Universität für Bodenkultur Wien
Department für Wirtschafts- und
Sozialwissenschaften

The future orientation of Austria's flood policies: from flood control to anticipatory flood risk management

Ralf Nordbeck, Reinhard Steurer & Lukas Löschner

InFER | Institute of
Forest, Environmental, and Natural Resource Policy

Diskussionspapier / Discussion Paper 2-2019

2019

University of Natural Resources and Applied Life Sciences, Vienna
Department of Economic and Social Sciences

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ISSN 2072-764X

Also published as

Ralf Nordbeck, Reinhard Steurer & Lukas Löschner (2019): The future orientation of Austria's flood policies: from flood control to anticipatory flood risk management. In: Journal of Environmental Planning and Management

Bestelladresse / orders to:

Institut für Wald-, Umwelt- und Ressourcenpolitik
Universität für Bodenkultur Wien
Feistmantelstr. 4
A – 1180 Wien
Tel: + 43–1–47 654–73200
e-mail: infer@boku.ac.at

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Eigenverlag des Instituts für Wald-, Umwelt- und Ressourcenpolitik, Universität für Bodenkultur Wien

Published by the Institute of Forest, Environmental, and Natural Resource Policy, University of Natural Resources and Life Sciences, Vienna (BOKU)

This paper analyses the future orientation of flood risk management in Austria. Framed by a systematic review of risk reduction measures, we assess the extent to which Austrian policies are characteristic of an anticipatory, forward-looking flood management approach to cope with expected future stresses on the flood risk, such as climate change and land development. The analysis shows that risk reduction measures build on status quo assessments and do not explicitly consider future changes in the flood hazard or vulnerability. However, new design standards for extreme events, the proliferation of large-scale flood retention, tightened land development and building restrictions, and novel planning instruments indicate that Austrian policies are increasingly forward-looking to more effectively mitigate future increases in the flood risk. This temporal reorientation is a consequence of a wider policy shift from flood control to integrated flood risk management. Faced with the increasing spatial interplay of risk reduction measures (e.g. securing land for flood runoff and flood retention), our analysis shows that inter-sectoral cooperation between water management and spatial planning can support long-term flood management decisions and maintain the ability to adapt to changing future conditions.

Keywords: flood risk management; anticipatory adaptation; risk reduction strategies; flood protection; floodplain development; climate change adaptation

1. Introduction

Floods are among the most common and most destructive natural hazards worldwide (CRED/UNISDR 2015). Between 1965 and 2015, Europe suffered more than 550 damaging flood events that claimed 5,388 lives, affected almost 16 million people and caused economic losses in excess of EUR 123.1 billion (CRED 2018). A closer look at global flood statistics shows a significant increase in the number of damaging flood events in the past 15 years. In line with this trend, Central European countries have experienced a series of major flood events in recent years, most notably along the Danube, the Elbe and their tributaries (in 2002 and 2013) and in the Western Alps (in 2005).

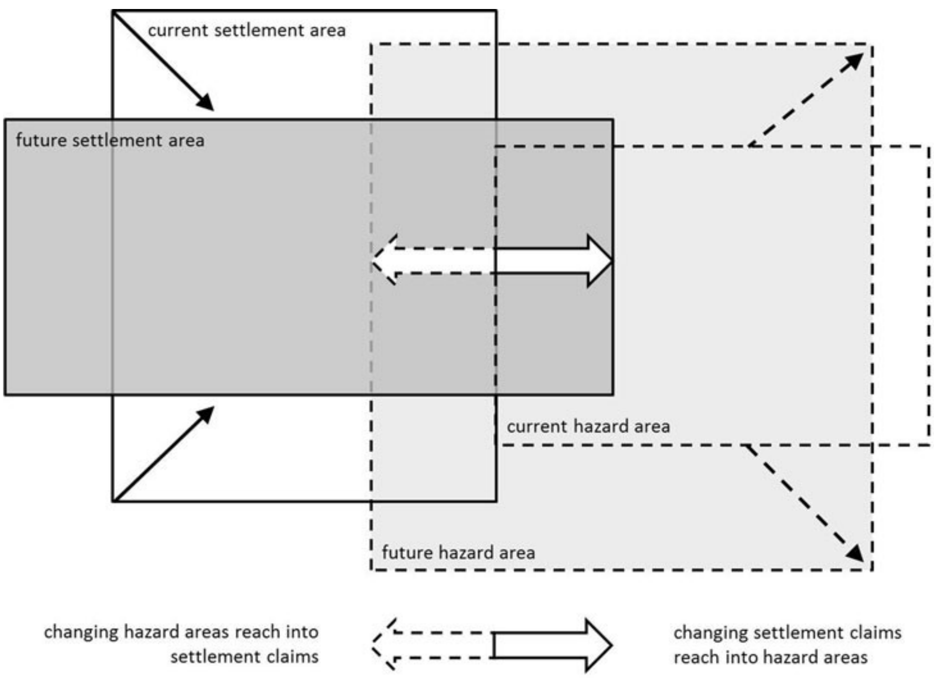

Figure 1. Spatio-temporal dynamics of flood risk (Reproduced by permission of ARE, BWG, BUWAL 2005).

In the wake of these events, policymakers across Europe agreed that flood policies required a fundamental reorientation (EC 2004). This consensus culminated in the EU Floods Directive (EFD)[1] (EC 2007). It defines common benchmarks for the assessment and management of flood risks across Europe and outlines a policy shift from a hazard-based approach of flood defense towards an integrated approach of flood risk management (Klijn, Samuels, and Os 2008). The Directive states that “human activities (...) and climate change contribute to an increase in the likelihood and adverse impacts of flood events” (EC 2007, 1). It acknowledges that both constituents of flood risk (hazard and vulnerability) are non-stationary (Milly et al. 2008) and that the flood risk is a dynamic entity (Merz et al. 2010). A key indicator of flood risk dynamics is the observed increase in flood damage in recent decades (Barredo 2009). This increase can be attributed to socioeconomic drivers, i.e. settlement growth reaching into hazard areas (see Figure 1), and there is a consensus that land development in floodplains has, and will continue to have, adverse effects on flood risk across Europe (Cammerer and Thieken 2013; Di Baldassarre et al. 2013; Thieken et al. 2016).

As another driver of flood risk in Europe, the empirical findings on climate change are less clear (Hall et al. 2014). A general climate-induced increase in the frequency and intensity of river flooding in Central Europe has not yet been detected in climate models (Kundzewicz 2015). Studies based on historic trend analyses have not found clear evidence for a widespread climate-driven change in the magnitude and frequency of floods during the last decades (Kundzewicz, Pinskwar, and Brakenridge 2013). However, a pan-European assessment of observed flood seasonality trends found that the changing climate has clearly shifted the timing of river floods during the past five decades (Bl€oschl et al. 2017). Without adaptation, such changes in flood seasonality can profoundly affect agricultural productivity, water supplies, irrigation and hydropower production.

In Austria, studies indicate that the recent succession of major floods is within the range of long-term flooding trends, with some decades showing more frequent and intense flooding than others (Bl€oschl et al. 2011). Although climate change affects temperature-dependent components of the Alpine hydrological cycle (e.g. rising snowline), due to the complexity and topographically induced variability of the Alpine climate, regional climate models are uncertain regarding the prediction of future river floods in Austria, especially for smaller catchments (APCC 2014).

In light of the expected, but uncertain, future changes in flood risk, there is a growing need to reorient flood policymaking from a retrospective, disaster-driven approach to a prospective, future-oriented approach “that adapts to the future as it becomes known” (Sayers et al. 2013, 55). This contribution explores this shift in flood policies using the example of Austria, which has been heavily affected by river flooding in the past 10–15 years. The study is framed by the following two research questions: How far have flood-related policies shifted from responsive approaches to past flooding events toward anticipatory approaches that also consider likely future developments?

To what degree is there a recognizable shift from simple hazard reduction through structural flood control to a more integrated approach of risk reduction that employs a broader portfolio of structural and non-structural measures?

The paper addresses these questions after describing the Austrian policy context and study area and outlining the study’s methodological approach in Section 2. Section 3 conceptually frames the need for adaptation in a changing flood risk environment. Based on different types of adaptation, we differentiate two broad strategies of flood risk reduction and four options to reduce flood risks: flood defense, load reduction, land development restriction and building regulation. Section 4 applies this typology to our analysis of contemporary flood risk management in Austria. Section 5 discusses our empirical findings and summarizes the main conclusions.

2.Policy context, materials and methods

Flood policymaking in Austria's federal system is characterized by a complex distribution of responsibilities across different levels and sectors of government (Kanonier 2009; Nordbeck 2014). In addition to water management and hydraulic engineering, this concerns spatial planning, which has emerged as a pivotal policy sector in Austria's shift toward integrated flood risk management (BMLFUW 2006). Water management and hydraulic engineering have the fundamental task of providing flood protection and reducing flood hazard potentials. Spatial planning can complement these aims by securing the necessary land resources for land-intensive hazard reduction measures. In addition, spatial planning can mitigate the increase in flood damage by regulating land development and the building design of exposed structures (White and Richards 2007).

The legal basis of water management and flood protection is defined in three main federal acts: the Water Act (WRG 1959), the Forest Act (FG 1975) and the Hydraulic Engineering Development Act (WBFG 1985). Policy documents, including the Technical Guidelines for the Federal Water Engineering Department (BMLFUW 2015a) and the National Flood Risk Management Plan (BMLFUW 2016), provide guidance concerning the implementation of flood risk management policies in Austria. At the state level, there are no legislative provisions for water management. However, state authorities exercise federal executive power (through indirect federal administration) and draft flood-related policy documents, such as water management strategies.
The main competencies concerning spatial planning are at the state level. Spatial planning laws and building codes have been passed in the nine Austrian federal states. State governments are also responsible for drafting regional spatial plans, which may be used to secure large-scale areas for flood retention and flood runoff. At the federal level, there are no legislative provisions for spatial planning in Austria. Federal and state interests in spatial planning are coordinated by an intermediary organization, the Austrian Conference on Spatial Planning (OROK).€

To account for the distribution of responsibilities between federal and state actors in flood risk management, this contribution analyzes federal and state flood policies in water management and spatial planning. Rather than cover all nine Austrian states superficially, we address two of them-Vorarlberg and Lower Austria-in greater depth. These states were heavily affected by large-scale flooding in recent years (Lower Austria in 2002 and 2006; Vorarlberg in 2005) and provide insightful cases for the study of policy change towards integrated flood risk management. Moreover, both states are characterized by a high level of flood hazard exposure that is likely to increase in the future (Fuchs, Keiler, and Zischg 2015; Nordbeck et al. 2015) due to potential climate-induced changes in flood discharges (Nachtnebel and Apperl 2015) and population growth in the urbanized areas of the Danube river basin in Lower Austria and the Rhine valley in Vorarlberg (L€oschner et al. 2016).

The study primarily draws on desk research and qualitative expert interviews. We reviewed the scholarly literature on expected climate- and land use-induced changes in flood risk policies. We also analyzed sectoral policies in water management and spatial planning at the federal level and for the selected states, based on a review of policy documents and legal frameworks. In addition, we analyzed planned and realized flood protection measures between 2010 and 2016, as documented in a flood protection database of the Austrian Federal Ministry of Sustainability and Tourism (BMNT) and based on data provided by the water management and spatial planning divisions of the two state governments.

Finally, we conducted 20 semi-structured interviews with 23 experts in Austrian flood risk management and climate change adaptation (see Annexure). The interviewees comprise scientific experts (n¼5), federal policy officers (n¼4), state officials (n¼10) and policy experts from affiliated national agencies (n ¼ 4). The interviews were recorded, transcribed and coded using Atlas.ti qualitative data analysis software.

3.Adaptive flood risk management: conceptual foundations

3.1.Adaptation in a changing flood risk environment

Traditional flood protection is characterized by a firm belief in controlling rivers via engineering solutions. In contrast, the paradigm of integrated flood risk management aims to reduce the severity of, and the vulnerability to, flooding based on a portfolio of approaches comprising structural and non-structural measures (Samuels, Klijn, and Dijkman 2006; van Herk et al. 2015). The transition also involves a change in the underlying understanding of flood risk. The traditional approach was characterized by a hazard-based understanding that defines flood risk as a function of the probability and the adverse consequences of flooding, which may be expressed in terms of flood damage, casualties, etc. The new approach revolves on a vulnerability-based understanding that conceptualizes flood risk as a function of flood hazard and vulnerability (Klijn et al. 2015). Whereas hazard is defined by the probability and the constituents (e.g. the water depth, water velocity), which determine the extent of harm for the elements at risk, vulnerability depends on the elements exposed in a hazard area and their susceptibility to harm (Gouldby and Samuels 2005).

Hazard and vulnerability reduction are associated with long-term commitments in water management and land-use planning (Hallegatte 2009). Due to considerable uncertainties of future changes in flood risk, these commitments must be (i) adaptive, i.e. they ought to have "the ability to change in response to altered circumstances" (Adger, Arnell, and Tompkins 2005, 81) and (ii) be robust to cope with a range of possible future conditions (Wilby and Dessai 2010; Mens et al. 2011). Flood risk management may thus be characterized as a "continuous process of adaptive management" (Hall and Solomatine 2008, 85).

Adaptation implies "the ability or capacity of a system to modify or change its characteristics or behavior to cope better with existing or anticipated external stresses" (Brooks 2003, 8). This also embraces the narrower notion of adaptation to climate change, i.e. "the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities (IPCC 2012, 556). Because clear climate signals on fluvial flooding are lacking (see Section 1), we employ the broad adaptation notion and define it as the totality of strategies, processes and measures that aim to reduce the risk of flooding in an ever-changing and uncertain risk environment (Howe 2011; Jongman et al. 2015).

The definitions introduced above implicitly distinguish two types of adaptation: responsive and anticipatory adaptation. Generally, responsive adaptation addresses existing stresses, whereas anticipatory adaptation is forward-looking and aims to cope with expected future stresses (Klein 1998; Smit et al. 1999; Merz et al. 2010). Applied in the context of flood risk management, the respective

temporal orientations of responsive and anticipatory adaptation determine four fundamental differences (see Table 1).
First, the adaptation types differ in terms of the design values for assessing flood protection levels and exceedance probabilities. In responsive adaptation, these values are statistically determined based on discharge data, ideally in consideration of recent

Table 1. Key features of responsive and anticipatory adaptation.

	Responsive adaptation	Anticipatory adaptation
Design values and protection levels	Historical runoff data incl. recent extreme events	Historical runoff data adjusted to future projections
Cost-benefit analysis	Based on current hazard and damage potentials	Considers projected socioeconomic and climatic changes
Spatial focus	Areas affected by past flood events	Areas at risk of future flooding
Temporal scope	"Take immediate actions" to improve flood protection	"Plan ahead" for expected future policy needs

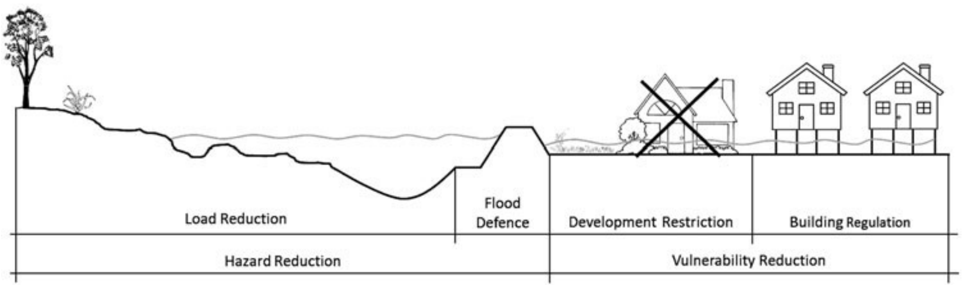

Figure 2. Strategies and options for risk reduction (authors' illustration).

extreme events, which may significantly influence the design values. In a forwardlooking approach (anticipatory adaptation), projections of expected future changes in precipitation and runoff are factored into the flood design (e.g. in the form of a 'climate allowance,' an additional freeboard or a flood frequency analysis based on simulated future discharge).

Second, the adaptation types also reflect different approaches to determine costbenefit ratios. Cost-benefit analyses (CBA) in responsive adaptation match the costs of constructing and maintaining flood defenses with the (status quo) benefits from the protection of existing settlements and other assets. In anticipatory adaptation, the CBA considers the projected socioeconomic changes (e.g. expected increases or decreases in vulnerable assets in the protected areas) and possible climate-induced changes in the flood hazard.

Third, the adaptation types are characterized by differences in their spatial focus. Responsive adaptation is 'disaster-driven,' as policy efforts to increase flood protection levels focus on areas that are heavily affected by flood events. In contrast, anticipatory adaptation is risk-based and directs risk reduction efforts to areas with a high future flood risk.

Finally, there are also differences in the temporal scopes of responsive adaptation and anticipatory adaptation. The former is characterized by immediate efforts to improve flood protection in affected areas, e.g. by building levees. In addition to such temporally focused actions, anticipatory adaptation is shaped by efforts to 'plan ahead' and maintain future generations' flood risk management capabilities, e.g. by securing large-scale areas for flood retention and runoff.

3.2.Strategies for flood risk reduction

An orientation toward responsive or anticipatory approaches in flood risk management can be employed through combined strategies of hazard reduction and vulnerability reduction (Hegger et al. 2014; Klijn et al. 2015; Alfieri, Feyen, and Baldassarre 2016; Bubeck et al. 2017). We distinguish four options for flood risk reduction: load reduction, flood defense, land development restriction and building regulation (see Figure 2). In this study, the scheme only accounts for risk reduction options that are under the direct legal responsibility of the water management and spatial planning sectors. Flood preparedness (including early warning) and flood recovery (e.g. disaster relief), as additional flood risk management strategies, are not considered in this study due to the involvement of other policy sectors and nongovernmental actors including civil protection, insurance companies and meteorological offices (cf. Hegger et al. 2014).

3.2.1.Hazard reduction strategies

Hazard reduction strategies aim to reduce the probability and intensity of a flood event through flood defense and/or load reduction:

Flood defense: Flood defenses protect people, buildings, property and other assets against certain design or reference floods (e.g. 100-year flood events). The absence of development restrictions beyond flood defenses may trigger settlement growth and the accumulation of assets in protected areas ("levee effect"). In extreme events, flood defenses may overspill or fail (breach), resulting in the activation of this damage potential and heavy losses in these protected areas (Collenteur et al. 2015; Fuchs et al. 2017). Defense structures can be permanent (e.g. dams, dikes or embankments) or provide temporary protection against floods, as in the case of mobile flood protection systems. Investments in flood defense infrastructure are long-term (up to 100 years and more) and are associated with high construction and maintenance costs (Hallegatte 2009).

Load reduction: Large-scale natural flooding areas have significant effects on wavelength prolongation and the most effective options to cap flood peaks are controlled retention basins or polders (Patt and J€upner 2013). Retention areas may serve as buffers to ease possible climate-induced increases in future flooding (EC 2009). Both natural and controlled retention areas are long-term, landintensive measures for flood prevention, whose implementation in practice is often hampered by conflicting land-use interests and property rights issues (Moss and Monstadt 2008; Hartmann 2011).

3.2.2.Vulnerability reduction strategies

Vulnerability reduction strategies aim to keep risk elements 'away from water' and/or limit the flood damage for risk elements. We distinguish between land development restriction and building regulation as follows:

Land development restriction: Decisions to develop floodplains may entail lockin situations that are "highly vulnerable to the underestimation of future risks" (Hallegatte 2009, 244). Active controls on land development (e.g. zoning bans or zoning restrictions) are effective means to limit the exposure of assets to flood hazards. Although they keep land development options open for the future, restrictions on land development also create indirect costs in terms of foregone tax revenues and inhibited economic development (Needham and Hartmann 2016).

Building regulation: To limit the damaging effects of floodwater on buildings, flood proofing measures at the level of individual households have been found to be cost-efficient and effective (Kreibich et al. 2005; Bubeck et al. 2012). These measures include wet flood proofing (e.g. strengthening walls against water pressure, elevating floor levels, securing oil tanks, using water-resistant materials) and dry flood proofing (e.g. sandbags, door panels). Flood proofing measures may be legally imposed through building codes or incentivized, e.g. through (housing) subsidies or flood insurance (Kreibich, Christenberger, and Schwarze 2011).

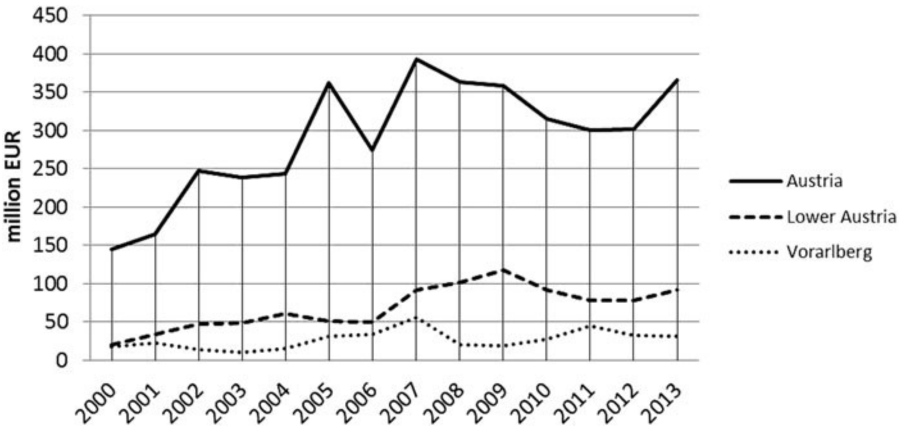

Figure 3. Annual expenditure on flood control, 2000–2013 (Reproduced by permission of Nordbeck (2014) and Sinabell et al. (2015).

4.Austria's changing flood policies

This section applies this categorization of risk reduction strategies to delineate Austria's changing flood policies. A general overview of programmatic and budgetary changes is presented, followed by a more detailed examination of the instrumental and regulatory changes. The section concludes by highlighting the aspects of Austria's flood policies that correspond with responsive or anticipatory adaptation.

4.1.Programmatic and budgetary changes

Following a series of devastating flood events in the late 1990s and early 2000s, European (see Section 1) and Austrian flood policies underwent significant changes (Nordbeck 2014). The succession of high-impact flood events in Austria (in 2002 and 2005) marks a decisive turning point in Austrian flood policy. According to a highlevel Austrian policy maker, the flood catastrophes were an "external shock" and ignited a "process of introspection" with the aim to inquire "how such immense damage could occur notwithstanding large investments in flood protection" (Interview_2).

In the aftermath of the 2002 event, a multi-sectoral research programme was enacted to evaluate Austria's flood policies (BMLFUW 2004). In response, Austrian policymakers were quick to embrace integrated flood risk management as a new policy paradigm. According to a 2006 policy document, integrated flood risk management promotes: (i) a holistic view of the risk cycle, integrating the three elements of prevention, response and recovery, (ii) the integration of flood management into other policy fields such as spatial planning, agriculture and forestry, transportation and tourism, and, (iii) individual solutions, e.g. through enhanced risk awareness among those potentially affected by floods and by facilitating precautionary measures with financial incentives (BMLFUW 2006).

Consequently, the Federal Water Engineering Administration committed itself to principles of sustainable flood protection and emphasized the importance of making use of the full spectrum of the measures introduced above (BMLFUW 2006). According to the Technical Guidelines for the Federal Water Engineering Department (RIWA-T), Austrian flood policies shall prioritize (i) non-structural measures of flood

Table 2. Key indicators of flood risk management in Austria for 2010–2016 based on data from the national flood protection database provided by the Austrian Ministry of Sustainability and Tourism.

Year	Hazard maps and plans [km]	Retention volume [m^3]	Linear flood defense [km]	Residents protected (100-year floods)	Buildings protected (100-year floods)
2010	60.3	41,830	9.3	1,980	761
2011	147.5	1,37,642	17.5	8,407	1,794
2012	416.7	3,061,945	1,334.7	17,675	4,273
2013	900.2	7,869,202	4,433.6	52,933	8,152
2014	47.2	3,786,320	51.5	31,174	9,116
2015	1,696.9	4,632,966	67.4	18,532	5,973
2016	1,541.1	1,839,560	30.6	13,030	2,815
Total	4,809.9	21,369,465	5,944.6	143,731	32,884

Note: The considerable year-to-year variations are due to the accounting periods.

management over structural measures, (ii) flood retention over linear flood protection and (iii) natural retention over technical/controlled retention (BMLFUW 2015a).

This "strategic orientation" (Interview_2) toward non-technical and planning measures was accompanied by a substantial increase in expenditure on structural flood protection measures following the flood events in 2002 and 2005. As Figure 3 illustrates, the total expenditure on flood protection increased from EUR 145 million in 2000 to EUR 360 million in 2005, reaching a maximum of EUR 390 million in 2007. After a slight decrease in annual expenditure, the flood event in 2013 brought flood-related investments back to more than EUR 360 million. The upward trend in federal expenditure is also evident on a state level. In both Lower Austria and Vorarlberg, annual spending on flood control increased considerably during the reference period. In Vorarlberg, the flood event of 2005 resulted in a nearly twofold increase in funding by 2007. In Lower Austria, the increase in expenditure was less pronounced following the 2002 flood, due to a series of flood, events in the late 1990s, which had already induced flood-related expenditure.

The annual expenditure on flood risk management (for the reference year 2010) shows that the bulk of spending concerns construction measures (64%), followed by the maintenance of existing flood protection structures (20%), whereas non-structural measures such as hazard zone planning (9%) and emergency response measures (7%) are less prominent in the expenditure (OECD 2013).

4.2.Instrumental and regulatory changes

Despite the rhetorical prioritization of non-structural measures (BMLFUW 2006, 2015a), structural flood protection is prominent on the Austrian flood policy agenda. As illustrated in Table 2, linear flood defenses and (controlled) flood retention basins are highly effective pillars of Austria's flood risk management: since 2010, more than 143,700 buildings and 32,900 residents have been protected against 100-year floods. These improvements were also made possible by the proliferation of hazard maps and superordinate plans on the river catchment level. They provide the necessary flood hazard and flood risk information for effective planning of future flood protection schemes, flood-adapted land development and building risk awareness in flood-prone areas (BMLFUW 2016).
Based on the conceptual distinction in the risk reduction options outlined above, the following section documents the instrumental and regulatory changes in Austrian flood policies: (i) flood defense (4.2.1.), (ii) load reduction (4.2.2.), (iii) land development restriction (4.2.3.) and (iv) building regulation (4.2.4).

4.2.1. Flood defense

Due to the long-term nature of large infrastructure projects, linear protection measures reached peaks in 2012 and 2013 (several years after their initiation following the 2002 and 2005 floods). The extreme flood in 2013 resulted in smaller, immediate measures and long-range projects, which do not yet list the available flood protection figures.

Since 2002, permanent flood defense structures were complemented by mobile defenses, particularly along large rivers with long early-warning periods. During the Danube flooding in 2013, mobile defenses proved to be highly effective solutions, especially for flood-prone historical settlements with limited space for conventional flood protection measures (Interview_7). Some top-level policy makers consider this technology as "probably the most fundamental innovation [in flood policy] in recent years" (Interview_6) because the public flood risk awareness is raised by complementary maintenance and emergency exercises (Interview_7).

Notably, the federal government also improved design standards such as the safety allowance (called 'freeboard' in Austria), which is added to the calculated design of flood defense infrastructure as a 'buffer' to accommodate for uncertainties (e.g. caused by driftwood) that are not accounted for by runoff models (Interview_15, Interview_18, Interview_19). Moreover, the Technical Guidelines for the Federal Water Engineering Department define controlled flood spillways for new defense structures (BMLFUW 2015a) to prevent an uncontrolled failure of flood protection infrastructure (cf. Interview_15; Interview_18; Interview_20).

4.2.2. Load reduction

Load reduction through natural retention areas and controlled retention basins has become a top priority in Austrian flood policy. According to the recently revised Technical Guidelines for the Federal Water Construction, retention measures shall be implemented where possible and open areas shall be preserved for flood runoff and retention. In addition, measures aggravating flood runoff shall be avoided and limitations in retention capacities must be compensated by additional retention space (BMLFUW 2015a).

The shift away from linear flood protection toward targeted flood retention, i.e. "flood retention instead of flood acceleration", constitutes a guiding principle of integrated flood risk management (Interview_18). This is also reflected in the National Flood Risk Management Plan, which highlights the importance of flood retention basins for load reduction (BMLFUW 2016). A review of the local flood risk management plans for Austria's 391 areas with potentially significant flood risk (APSFR) reveals that controlled retention measures are a top priority in the portfolio of flood risk management in more than 56% of the APSFR (Stiefelmeyer 2015). In contrast, the restoration of flooding areas, e.g. by reconnecting rivers and floodplains, widening rivers or removing dams, is considered a top priority in only three of the 391 APSFR. This is due to (i) the limited effectiveness of natural flood retention for risk reduction and (ii) the spatial focus of Austria's APSFR on urban areas.
Table 2 confirms the growing importance of controlled flood retention. As a result of the major flood events in 2002, 2005 and 2013, a large amount of additional retention was created: between 2010 and 2016, a retention volume greater than 21.3 million m^3 was allocated countrywide. In the long-term average, the annual additional retention volume is 500,000 m^3 (BMLFUW 2015b). Findings form the case study regions also document the increasing importance of flood retention. In Vorarlberg, 1.8 million m^3 or 142.5ha retention space was created from 2010 to 2014 (Government of Vorarlberg 2016).

The proliferation of flood retention was fostered by changes in the funding schemes, which determine that the acquisition and/or compensation of land and properties (e.g. for flood retention areas or areas compensating for the loss of flood retention) are eligible for federal funding (BMLFUW 2015a). Federal funding rates may increase or decrease depending on whether flood protection measures create, maintain or reduce the available space for flood runoff and flood retention (BMLFUW 2015a).

Notwithstanding favorable policy settings, the availability of land is a limiting factor for the practical implementation of flood retention measures (BMLFUW 2016). Especially in Alpine areas where the space for permanent settlement is topographically limited, potential retention areas in low-lying areas are subject to competing land-use interests. The land may be required for future settlement growth and economic development, but allocating (agricultural) land for flood retention and flood runoff often comes with restrictions on agricultural cultivation and may inhibit (profitable) land development options, e.g. due to rezoning into building land. Given the competing land-use claims and the high costs associated with land acquisition, the practical implementation of flood retention measures is often described as a "cumbersome and costly procedure" (Interview_14). As a result, the policy focus is increasingly shifting from large- to small-scale retention measures in the headwaters of river catchments (Interview_7; Interview_14; Interview_15; Interview_18; Interview_19). Moreover, water management policies increasingly foster the integration of land-related policy sectors, particularly agriculture and spatial planning (Government of Vorarlberg 2016; Interview_14).

4.2.3.Land development restriction

Land-use change is considered the most significant driver of future flood risk in Austria (Interview_2; Interview_3; Interview_12; Interview_15). In the 2000s, flood risk prevention through precautionary spatial and land-use planning became a major concern in Austrian flood policy (Habersack et al. 2015), indicating that integrated flood risk management in Austria marks a "necessary reaction to the dynamic [societal] change" (Interview_6).

This shift toward integrated flood risk management is reflected in changing landuse policies at different levels of government. Although the federal government does not have the competence to regulate land development (see Section 2), non-binding policy documents of the Austrian Conference on Spatial Planning (OROK), including€ the policy recommendations (OROK-Empfehlungen) for state policy makers, address€ the flood-related implications of spatial planning and support provincial and municipal spatial planning.

The comparison of the OROK recommendations related to natural hazards (€ OROK€ 1986, 2005, 2017) documents a fundamental shift concerning the roles of land use and spatial planning in Austria's flood policy (Interview_3). The first hazard-related planning document merely highlights the lack of available hazard information and the basic need for better consideration of natural hazards in spatial planning (OROK€ 1986). Following the extreme event in 2002, policy recommendations in 2005 formulate aims to strengthen the role of spatial planning for flood prevention and risk reduction (OROK€ 2005). The most recent document acknowledges the nationwide progress in land-use regulations and recommends a stronger risk orientation in spatial planning, i.e. by defining risk reduction as a fundamental concern for spatial planning in planning laws (OROK€ 2017).

On the state level, the reformulation of zoning restrictions for building land in hazard areas is an effective tool to mitigate increases in flood damage (Interview_3; Interview_8). As one of a few Austrian states, Lower Austria enforces a general zoning ban for building land in 100-year flooding areas (§ 26 Abs. 2 lit b, NO ROG€ 2014), although the state Planning Law allows for a number of exceptions for land development in flood-prone areas, particularly for agricultural land. In contrast, the Spatial Planning Act of the state of Vorarlberg does not define zoning bans for building land with reference to specific flood recurrence levels because a ban similar to that in Lower Austria would severely inhibit land development in many flood-prone Alpine valleys (Interview_13). The law states that unsuitable areas for building development due to natural conditions (e.g. flood hazard and groundwater) shall not be zoned as building land unless protective measures are technically and economically feasible (§ 13 Abs. 2, Vbg RPG 1996). In planning practice, 30-year flooding areas are generally not zoned as building land (Kanonier 2005).

Concerning regional approaches in flood-related spatial planning, in 2013 the Vorarlberg state government issued a legally binding regional spatial plan (the "Blauzone Rheintal") that designates flood runoff and flood retention areas along the Rhine and its tributaries (Government of Vorarlberg 2013). This planning instrument aims to (i) protect existing settlement areas and areas zoned as building land against flooding, (ii) preserve open areas for flood retention and flood discharge and (iii) secure areas for future flood control measures, such as relocating the Rhine outlet into the Bodensee due to rapidly progressing sedimentation (Government of Vorarlberg 2013). In a region characterized by strong land development pressures, this instrument prevents the further encroachment of settlements into hazard areas and secures areas needed for large-scale engineering works, preserving the "ability to adapt to changing future conditions" (Interview_15).

Imposing restrictions on undeveloped zoned building land in hazard areas remains a serious challenge because they interfere with existing private land-use rights (Interview_3; Interview_6; Interview_12). However, state and municipal governments have applicable legal instruments. In Lower Austria, the Spatial Planning Act entitles local authorities to impose a building ban if hazard assessments show that an undeveloped building area is affected by 100-year flood events (§ 26 Abs. 2 lit b, NO ROG€ 2014). Moreover, municipalities are urged to re-zone building land into open land without compensation if it is threatened by 100-year floods. In Vorarlberg, local authorities can re-zone building land into open land if it is considered unsuitable for land development (§ 27 Abs. 2, Vbg RPG 1996). However, for the reasons noted above, these options are rarely implemented (BMLFUW 2015b; Interview_3). In Lower Austria, for instance, only a fraction of the building land in flood-prone areas has been re-zoned into open land (Interview_18), usually including compensation (Interview_17).

Finally, the relocation of buildings (and residents) from hazard areas–as a particularly 'invasive' measure and thus politically highly sensitive vulnerability reduction (Interview_6)–is not treated in any of the Austrian states' Planning Acts. Although relocations have been conducted in several parts of Austria, including in both case study regions, it represents a "means of last resort" (Interview_17) and there are no legal or planning instruments for the mid- to long-term anticipatory transformation of developed flood-prone areas into flooding areas (Kanonier et al. 2015).

4.2.4. Building regulation

Assessments of the flood events in 2002 and 2005 showed that, in many cases, flood damage could easily have been reduced or avoided through dry and wet flood proofing (BMLFUW 2004, 2009a). In 'flood-protected' areas, flood proofing is considered a private responsibility, as those potentially affected are expected to take individual precautions to mitigate flood damage. In recent years, efforts have been made to promote public knowledge and awareness of flood hazards and flood risk (BMLFUW 2009a; Habersack et al. 2015). For instance, in Lower Austria, in addition to building risk awareness, flood proofing measures are incentivized through housing subsidies (NO€ WF-RL 2015). In Vorarlberg, the policy focus is on raising awareness for flood hazard/risk and state fire brigades create an information service to promote private flood prevention measures and flood proofing in hazard areas (Interview_14; Interview_15).

In flood-prone areas that are suited for development, legally binding regulations are increasingly used to promote the construction of flood-adapted buildings. For example, the building code of Lower Austria requires that the floor levels of living rooms must be at least 30cm above 100-year flood levels (§37 Abs. 1 Z 3, NO€ BauTV) and that combustible fluids must be stored in a flood proof manner (§ 61 Abs. 2 BauO, NO BauO€ 2014). An extension of such building regulations to pluvial hazard areas is under consideration (Interview_17; Interview_18). Facing an increase in heavy rainfall, as a likely result of climate change, the Government of Lower Austria has recently developed a state-wide hazard map for surface runoff, which could provide a comprehensive hazard information base for flood proofing measures in areas prone to pluvial floods. In Vorarlberg, policymakers do not want to 'overregulate'. Due to the confined topographic conditions, building regulations in hazard areas are generally contested (Interview_12), thus policy efforts focus on fostering voluntary private adaptation measures by raising the awareness for extreme flood events and residual flood risk (Interview_12). Accordingly, the building code in Vorarlberg is less specific; it merely states that a building plot may only be developed if the building itself or neighboring properties are not threatened by natural hazards (§ 4 Abs. 4 BauG, Vbg BauG 2001).

4.3. Adaptive flood risk management in Austria?

Based on the conceptual distinction between responsive and anticipatory adaptation (see Section 3.1), this section highlights the key features of adaptive flood risk management in Austria.

4.3.1. Design values and protection levels

Flood protection levels are generally designed based on the statistical probability of occurrence (using runoff data available at gauge stations). After extreme events, design standards are often adapted to account for the changes in the runoff statistics (cf. Government of Vorarlberg 2015). However, for various reasons, the experts interviewed predominately do not see a need to account for possible climate-induced changes in flooding, e.g. in the form of a precautionary climate allowance in runoff calculations (as in parts of Germany, cf. Kuklicke and Demeritt 2016). First, they note the lack of scientific evidence that flooding will increase in Austria due to climate change (see Section 1). Second, a precautionary climate allowance is considered to drastically increase the costs of structural flood protection (Interview_2; Interview_5; Interview_14), which would reduce the number of projects that can be implemented (Interview_5; Interview_12). Third, some experts consider such a precautionary orientation in structural flood defense to be in conflict with the federal prioritization of non-structural measures and assume that raising protection levels could increase the damage potential in protected areas (Interview_2; Interview_15). Several experts note that potential climate change impacts are already incorporated into planning practice as safety margins and stress that adding a climate allowance would divert attention from non-structural measures back to traditional flood defense (Interview_2; Interview_15).

4.3.2. Cost-benefit analysis (CBA)

The Hydraulic Engineering Development Act (WBFG 1985) prescribes CBA for hydraulic engineering measures with building costs higher than EUR 110,000. All CBA must follow the federal guidelines, which specify how the costs of constructing and maintaining flood defenses shall be matched with the benefits from the protection of existing settlements and other assets (BMLFUW 2009b). Although structural defenses have a lifespan of up to 100 years, these assessments only consider the current levels of flood hazard and current exposure (i.e. affected people and buildings) (BMLFUW 2015a). Austrian policy makers acknowledge socioeconomic change and land development as key drivers of future flood risk, but future demographic or socioeconomic developments (Interview_15; Interview_19) or possible climate-induced changes in flood runoff (see above) are not considered in CBA.

4.3.3. Spatial focus

The proliferation of hazard maps and superordinate plans on the river catchment level provide the necessary flood hazard and flood risk information to direct hazard reduction and vulnerability reduction measures to high-risk areas. Although flood risk management projects continue to be ‘hazard-driven’ in the sense that they are often implemented in areas that have been severely affected by flood events, the implementation of the EU Floods Directive and identification of the APSFR has helped identify areas with urgent needs for action and thus supports the shift toward anticipatory adaptation in flood risk management.

4.3.4. Temporal scope

The policy shift from defense-oriented approaches of flood protection toward integrated approaches in flood risk management changes the temporal scope of risk reduction measures in Austria. To 'accommodate' water on land (Wesselink 2007) and to secure areas for flood retention and flood runoff and for future flood defense measures (cf. 'Blauzone Rheintal,' Section 4.2.3.), there is a growing need to 'plan ahead' and maintain space for future generations to utilize in flood risk management. The growing importance of spatial planning in Austria's flood risk management supports this transition toward anticipatory adaptation.

5.Discussion and conclusion

This paper analyzed the degree that Austrian flood risk management has shifted (i) from primarily structural hazard reduction to a broader, more integrated approach to risk reduction and (ii) from responsive to anticipatory policies that consider past developments and likely future development. The findings show that, after the extreme flood events of 2002 and 2005, Austrian flood policies shifted from structural flood defense to a broader portfolio of vulnerability-oriented flood risk management measures. This shift entails new horizontal and vertical governance approaches, stricter land use and building regulations considering flood risks, and a massive increase in floodrelated expenditure. Although the bulk of the latter is still spent on structural flood protection, substantial amounts have been used for retaining floodwater to reduce peak flows. This change may be the single most important indication of the ongoing shift towards integrated flood risk management. Although the increase in non-structural measures may not have reversed the balance between hazard and vulnerability reduction strategies, it has certainly boosted the latter. We conclude that federal and state governments have shifted their focus from "providing protection against floods" to "optimizing safety levels" (Interview_6). The Austrian flood risk management plan (BMLFUW 2016) reveals that the current trend for combining preventive and protective measures will be carried forward into the next planning period for 2015–2021. However, the local flood risk management plans for Austria's 391 areas with significant flood risk indicate a prioritization of flood defense measures (including retention basins) over non-structural and planning measures in Austrian municipalities (BMLFUW 2016).

The findings indicate an apparent paradox that anticipatory policies are also a response to past events, implying that reactive and anticipatory approaches represent a continuum with hybrid approaches in between, rather than diametric opposites. Adaptation to (likely future) flood risks is a multi-causal process in which uncertain climatic factors are greatly overshadowed by highly likely socioeconomic trends, such as land-use change induced by population and/or economic growth. However, the temporal orientation of many policies may mitigate future increases in flood damage. This shift toward anticipatory adaptation marks a necessary consequence of the wider policy shift from flood control to integrated flood risk management. Faced with the increasing spatial interplay of risk reduction measures, e.g. securing land for flood runoff and flood retention, the future-oriented policies analyzed above are ideal examples for horizontally integrated flood risk management between water management and spatial planning. As an integrated, multi-sectoral endeavor, future-oriented flood risk management can support long-term flood management decisions and maintain the ability to adapt to changing future conditions. The federal states play a major role in this shift toward flood mitigation and prevention. First, they often act as policy entrepreneurs for innovations in flood risk management and spatial planning due to the distribution of responsibilities in the Austrian federal system. This is particularly true for the differentiation of vulnerability reduction strategies in recent years. The regulatory changes in Lower

Austria and Vorarlberg discussed in Section 4.2. are good examples of this decentralized approach, providing evidence for the argument that policymakers and officials in the federal states have sufficient incentives to innovate (Galle and Leahy 2009). Second, the states act as interfaces between the national and the local level in terms of communication, information and financial management. Support from state officials is often key for the realization and implementation of flood mitigation and prevention projects (Thaler, L€oschner, and Hartmann 2017).

This case study on flood risk management in Austria confirms many findings in other European countries, particularly the incremental nature of change and the importance of cultural and institutional barriers. We also confirmed the role of floods as a catalyst for institutional change (Bubeck et al. 2017; Wiering et al. 2017). Compared to the continuity and stability of flood risk governance in other EU member states (Gralepois et al. 2016), the governance arrangement in Austria has experienced greater changes in terms of actor coalitions, discourses, resources and rules. As a result, there is a diversification of flood risk strategies in addition to the previously dominant focus on flood defense, effective multilevel governance across political and administrative levels, and a multisector approach to integrate flood management and spatial planning (Fuchs et al. 2017). These changes in the governance regime occurred over a long time period and were triggered by several factors. The series of extreme flood events in 2002, 2005 and 2013 attracted public attention, put the issue high on the political agenda and created the political pressure necessary to act. The occurrence of three extreme floods in a decade generated several windows of opportunity to impose stricter rules and policies. The adoption of the EU Floods Directive in 2007 also supported these changes. Although the growing concern about climate change had little impact on flood governance in Austria until now, the improved evidence base for current and future risks concerning land development in hazard areas had a major influence on the flood risk discourse and provides the basis for enhancing an anticipatory approach in the Austrian flood risk governance regime.

Flood-related research can support this policy shift by exploring two issues in further detail. A fundamental issue is the sectoral interplay between water management and spatial planning. While the idea that water management and spatial planning need to collaborate in the field of flood risk management is established and widely accepted (Wiering and Immink 2006), more in-depth studies of policy coordination between the two sectors are needed to better understand the implementation challenges related to anticipatory flood risk management. This includes, on the one hand, output-oriented approaches to explore in further detail the possibilities and limitations of "[adjusting] sectoral policies in order to make them mutually enforcing and consistent" (Stead and Meijers 2009, 322). On the other hand, there is also need for process-oriented perspectives to cross-sectoral flood policy-making, which investigate the origins, the driving forces and the actors that promote flood policy change. Such approaches could help explain how, in the aftermath of a shock event, a redistribution of resources and power occurs and how advocacy coalitions in flood risk management translate their beliefs into actual flood policies (Meijerink 2005).

Secondly, there is a need to build a better understanding about possibilities and constraints of mobilizing land for flooding. While land resources are emerging as a critical factor in flood risk management, the provision of the necessary land (e.g. for flood storage, emergency flood runoff or river widening) is often hampered by the lack of availability and accessibility of the often privately owned land. Fundamentally, policy efforts are overridden by a conflict of interest between the public aim to provide land for flooding and the private interest (to limit infringements to private property rights and maintain opportunities for land development) (Kenyon, Hill, and Shannon 2008). Further research is needed to explore this policy delivery gap (Moss 2008) and the instruments by which to overcome it.

Note

1. EU Directive 2007/60/EC on the assessment and management of flood risks.

Acknowledgements

We thank the Austrian Climate and Energy Fund for financing the Flood-Adapt project that led to the present paper. It also benefited from the findings of the RiskAdapt project.

Disclosure statement

No potential conflict of interests was reported by the authors.

Funding

This study was funded by the Austrian Climate and Energy Fund for financing the Flood-Adapt project [grant number: KR14AC7K11809]; RiskAdapt project [grant number: KR11AC0K00275].

ORCID

Ralf Nordbeck http://orcid.org/0000-0002-6152-0830
Reinhard Steurer https://orcid.org/0000-0002-5000-7046
Lukas L€oschner https://orcid.org/0000-0001-7504-8007

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