Stakeholder analysis combined with social network analysis provides fine-grained insights into water infrastructure planning processes

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Abstract

Environmental policy and decision-making are characterized by complex interactions between different actors and sectors. As a rule, a stakeholder analysis is performed to understand those involved, but it has been criticized for lacking quality and consistency. This lack is remedied here by a formal social network analysis that investigates collaborative and multi-level governance settings in a rigorous way. We examine the added value of combining both elements. Our case study examines infrastructure planning in the Swiss water sector. Water supply and wastewater infrastructures are planned far into the future, usually on the basis of projections of past boundary conditions. They affect many actors, including the population, and are expensive. In view of increasing future dynamics and climate change, a more participatory and long-term planning approach is required. Our specific aims are to investigate fragmentation in water infrastructure planning, to understand how actors from different decision levels and sectors are represented, and which interests they follow. We conducted 27 semi-structured interviews with local stakeholders, but also cantonal and national actors. The network analysis confirmed our hypothesis of strong fragmentation: we found little collaboration between the water supply and wastewater sector (confirming horizontal fragmentation), and few ties between local, cantonal, and national actors (confirming vertical fragmentation). Infrastructure planning is clearly dominated by engineers and local authorities. Little importance is placed on longer-term strategic objectives and integrated catchment planning, but this was perceived as more important in a second analysis going beyond typical questions of stakeholder analysis. We conclude that linking a stakeholder analysis, comprising rarely asked questions, with a rigorous social network analysis is very fruitful and generates complementary results. This combination gave us deeper insight into the socio-political-engineering world of water infrastructure planning that is of vital importance to our well-being.

1. Introduction

The aim of this paper is to investigate planning processes in the water infrastructure sector, and to see how actors representing different levels (local, cantonal, national) and sectors (water supply, wastewater treatment) are integrated into these processes. Questions are: who plays an important role, what interests are represented, and how are the affected actors represented? Traditionally, such questions have been addressed via stakeholder analysis (e.g. Grimble and Wellard, 1997). Because environmental policy processes comprise complex modes of integration among actors from different hierarchical levels and across sectorial boundaries, social network analysis offers a more quantitative approach to investigate collaborative processes (e.g. Kenis and Schneider, 1991). Reed et al. (2009) identify a research need that investigates the potential of combining existing methods. Our study targets this gap by investigating the added value of combining a classical, qualitative stakeholder analysis based on semi-structured interviews with the more quantitative and rigorous approach of a social network analysis.

Water infrastructure planning for industrialized countries is typically dominated by engineers, and little social science research is being carried out in this field. Exceptions are numerous socio-economic studies designed to elicit the willingness to pay for water infrastructure services (e.g. Hensher et al., 2005; MacDonald et al., 2010; Willis et al., 2005). The often massive infrastructure investments made in developing countries, which often fail to benefit the local population, have been critically analyzed. Here, research related to water infrastructures comes from different fields of social science, such as conflicts about the fair allocation of water resources (e.g. Anand, 2012; Gopalakrishnan et al., 2005; Kujinga, 2002; Schaffer Boudet et al., 2011), detrimental health effects due to (lack of) sanitation (reviewed by Isunju et al., 2011; van Vliet et al., 2011), as well as economic aspects, e.g. investments in water supply infrastructures (Davis et al., 2001). This paper hopes to demonstrate the importance of including non-technical approaches in technically-oriented planning procedures, including industrialized countries, where conflicts about diverging stakeholder interests are less evident. Methodologically, we hope to reveal the added value of integrating stakeholder with social network analysis to overcome the shortcomings of purely qualitative approaches. Although they are based on a local case, our results can be generalized to water infrastructure planning in other countries, and can also be adapted to other problems requiring a careful analysis of the stakeholders involved.

1.1. Stakeholder analysis

Participatory methods are widely seen as essential to address the difficulties of environmental policy and decision-making. Stakeholder analysis is one of the most popular approaches to better understand the interests of the main parties. According to the early definition by Grimble and Wellard (1997), "stakeholder analysis can be defined as a holistic approach or procedure for gaining an understanding of a system (...) by means of identifying the key actors or stakeholders and assessing their respective interests in the system". For more specific definitions, also see the reviews by Brugha and Varvasovszky (2000) and Reed et al. (2009).¹ However, although extensively applied, stakeholder analysis in the narrow sense is

¹ "Stakeholder analysis aims to evaluate and understand stakeholders from the perspective of an organization, or to determine their relevance to a project or policy. In carrying out the analysis, questions are asked about the position, interest, influence, interrelations, networks and other characteristics of stakeholders, with reference to their past, present positions and future potential," (Brugha and Varvasovszky, 2000)

"We define stakeholder analysis as a process that: i) defines aspects of a social and natural phenomenon affected by a decision or action; ii) identifies individuals, groups and organizations who are affected by or can affect those parts

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often done on an ad hoc basis (Reed et al., 2009) and laundry lists of concerns are collected (Hermans and Thissen, 2009). Stakeholder analysis is criticized as somewhat wanting with respect to analytic quality and academic rigor, and there seems to be considerable confusion over the concept and practice (Reed et al., 2009). On the other hand, earlier papers already recognized that stakeholder analysis can encompass various methods of analyzing stakeholder interests (Brugha and Varvasovszky, 2000). The classic paper by Grimble and Wellard (1997) observed developments parallel to stakeholder analysis that can support decision-making in the case of conflicting objectives (multi-criteria analysis) or can address policy disputes (conflict or alternative dispute resolution). Recent systematization has provided a typology of stakeholder analysis methods (Hermans and Thissen, 2009; Reed et al., 2009).

1.2. Social network analysis

Environmental policy processes in general, and infrastructure planning and implementation in the water sector in particular, are characterized by collaborative modes that integrate local actors and different sectors (Bolleyer and Börzel, 2010; Lubell and Fulton, 2007). One promising approach to investigate such collaborative and multi-level governance settings is social network analysis (Kenis and Schneider, 1991; for methodological details see Scott, 2000). Social network analysis is defined as a method based on the assumption that relationships among interacting units are important (Wasserman and Faust, 1994). It is further said to encompass theories, models, and applications that are expressed in terms of relational concepts or processes (ibid). Applied to policy analysis and implementation, social network analysis concentrates on structural patterns between actors. In contrast to state-centric perspectives on policy-making, the network approach assumes that informal decision-making arrangements and the involvement of non-state actors are crucial aspects (Adam and Kriesi, 2007). Traditionally, network boundaries were defined following the hierarchical organization of public policies (Laumann and Knoke, 1987). To account for the complexity of environmental problems, current natural resource policy studies (Crona and Bodin, 2006; Prell et al., 2007), and water policy studies in particular (Ingold et al. 2010; Lubell and Fulton, 2007) have redefined the network boundaries to account for the multi-level, cross-sectoral and trans-boundary characteristics of actor identification. A social network analysis seems particularly suitable for this research, as it is capable of grasping the structural patterns of actors involved in planning processes, and can thus go beyond formal institutional settings (Scholz and Wang, 2006). This is relevant when assessing natural resource and water management that is not (only) characterized by top-down centralized decision-making and implementation structures (Ostrom, 1990; Pretty and Ward, 2001). Referring to different patterns of relational ties as structural characteristics of the networks can ultimately lead to conclusions about their impact on enhancing knowledge transfer, resource mobilization and consensus building (Bodin and Crona, 2009; Carlsson and Sandström, 2008; Newig et al., 2010). Specifically, after identifying the important actors in a first step, social network analysis allows us to analyze the actors' relational patterns and the overall process structure. The fragmentation and multi-level arrangements of actor networks can be assessed, and the central importance of single key stakeholders outlined.

of the phenomenon (this may include nonhuman and non-living entities and future generations); and iii) prioritizes these individuals and groups for involvement in the decision-making process," (Reed et al., 2009)

1.3. Combining stakeholder with social network analysis

Stakeholder analysis as presented above asks which actors should be included (see Weible, 2007). One added value of the research presented here is that the first crucial step of social network analysis – namely identifying network boundaries and thus the main actors as the unit of analysis – is done via a systematic stakeholder analysis. Stakeholder analysis accounts for 1.) the consideration of important and affected actors in the case study; and 2.) the multi-actor character (see Hermans and Thissen, 2009) of water infrastructure planning that transcends hierarchical boundaries. The identification of actors to be integrated in policy networks also explains why some scholars do not distinguish between stakeholder and social network analysis at all: the latter can even be defined as an integrated part of stakeholder approaches (see Hermans and Thissen, 2009; Reed et al., 2009).

At the core of social network analysis is a systematic and quantitative analysis of the relationships among the actors. In our case, this allows us to identify the process structures in water infrastructure planning in detail and to verify hypotheses regarding the presumed fragmentation of the water sector and the central role of certain actors. The rigorous approach of social network analysis allows us to address research questions that cannot be analyzed in adequate depth by stakeholder analysis. Insights from social network analysis can then be fed back into the stakeholder analysis. To answer the question as to whether actors perceived as important by others are integrated in the core or the periphery of the analyzed process, the social network analysis results are used to inform the stakeholder analysis (see also Prell et al., 2009). This example shows how both stakeholder analysis and social network analysis can be mutually supportive and fill the gap already addressed by Grimbé and Wellard (1997: 190) that stakeholder analysis can be improved by the incorporation of systematic methodologies and social actor approaches.

1.4. Water infrastructure planning

Our study case is infrastructure planning in the water sector. Built by the past generation, the water supply system provides water to households, industries, for firefighting, urban landscaping and sometimes to agriculture in drinking water quality and sufficient quantity at all times. The wastewater disposal system ensures urban hygiene, drainage of storm water and the environmentally safe disposal of pollutants. Our infrastructures, however, are expensive and ageing², and need replacement to ensure the continued provision of services. Because of their longevity (pipes last 50–100 years), water infrastructures are planned into the far future. In Switzerland as elsewhere, infrastructures are planned with the help of projections from the boundary conditions of the past, a questionable approach in an increasingly dynamic world. The wastewater treatment system is already reaching its limits. As example, pharmaceuticals in water bodies remain an unresolved issue (e.g. Kummerer, 2009). In future, climate change is likely to exert strong pressure, and water infrastructures will have to cope with changed precipitation patterns, namely extreme droughts and more frequent heavy storms (e.g. Kysely et al., 2011). Various authors have identified the challenges to water infrastructures as demanding, to put it mildly. Indications are growing that current engineering practices, available financial resources, and the system's capacity are likely to be insufficient (e.g. Arnbjerg-Nielsen and Fleischer, 2009; Butler et al., 2007; Milly et al., 2008; Patz et al., 2008).

² The replacement values of the public system (i.e. without private house connections) are typically US\$ 2,600 cap⁻¹ for large countries (I, UK, F, D, USA), and US\$ 4,800 cap⁻¹ for small countries (DK, CH, A; Maurer et al., 2005). The annual investment need in OECD countries in the aging water sector is estimated at 0.75% of GDP (Cashman and Ashley, 2008), which translates into US\$ 300,000 million annually (OECD, 2012).

Switzerland is a typical OECD country whose water supply and wastewater systems are mainly operated and owned by public sector organizations, often local communities. As in the USA, Canada, New Zealand, China, India, the Netherlands, and Germany, private provision in the water infrastructure sector is significantly below 20% (Dominguez et al., 2009).³ There are around 3,000 water supply companies and 1,000 wastewater treatment plants (WWTPs) serving Switzerland's 7.9 million inhabitants. This strong fragmentation of the urban water management sector causes considerable deficiencies. Recently, longer-term strategic planning projects have attempted to address these problems (e.g. Dominguez et al., 2009; Lienert et al., 2006; Truffer et al., 2010). The Swiss example can be regarded as representative of utility sectors with predominantly public forms of organization and highly localized structures (Dominguez et al., 2009). Typically, water utilities consist of a general management responsible for their operation, and a supervisory board responsible for strategy whose members come from the municipalities which own the utility. Several municipalities often form partnerships of convenience, or if they are private corporations, the communities are the only shareholders. Infrastructure planning is usually contracted out to an engineering company. Especially in smaller communities, integration across community borders or between sectors is rare (this applies to water supply and wastewater, but also to the energy and gas supply, or road works). In many countries, these network-bound infrastructure systems typically follow their own, sector-specific management regime, which is characterized by separate technical and institutional structures (Konrad et al., 2008). In the water sector, the observed divide between water provision and wastewater disposal (ibid) has given rise to particularly strong criticism by urban water management professionals (e.g. Daigger, 2009). In Switzerland, although the population pays for the system, planning is not usually participatory.

1.5. Aims and hypotheses

We focus on an exemplary and typical Swiss case consisting of several small communities. We are interested in how actors from different decisional levels and sectors are represented in the decision processes and which interests and stakeholders are important.

The water sector, along with other network-bound infrastructure systems, is undergoing fundamental transformations across the world (e.g. Konrad et al., 2008; Moss, 2009). Shifts in management style have been documented in various countries, such as in the Netherlands (van der Brugge et al., 2005), Germany (Konrad et al., 2008), and – involving a struggle with the privatization model – in England and Wales (Bakker, 2003, 2005; Guy, 1997). Water management in general, and infrastructure planning in particular, are thus challenging current institutional and top-down organized settings (see Hering and Ingold, 2012). This may result in new actors entering the field to perform new tasks (Moss, 2009). Generally, planning processes may become fragmented in such a way that actors representing different sectors and levels are more or less well integrated (Hooghe and Marks, 2003; Louka, 2008). This holds true particularly in Switzerland, where the federalist setting gives specific power to local units (Vatter, 2006), and there are few accounts of more far-sighted, integrative planning processes in the water infrastructure domain (e.g. Dominguez et al., 2009; Lienert et al., 2006; Truffer et al., 2010). As an example, strategic planning with three representative Swiss wastewater utilities (Bern, Kloten-Opfikon and Dübendorf) resulted in strategies aimed at growth for all three case studies, albeit in different directions (vertical, horizontal or geographical; Dominguez et al., 2009). Deducing from that and from Section 1.4, we hypothesize that the fragmented, small-scale Swiss governance structure is mirrored in infrastructure planning:

³ Few countries (e.g. UK, France, Czech Republic, and Spain for the sewerage services) are served to around 50% by private companies.

H1: Horizontal fragmentation: There is very low integration among different sectors.

Specifically, there is a strong division between the water supply and wastewater sectors.

H2: Vertical fragmentation: Little collaboration exists between actors belonging to different decisional levels (i.e. local, cantonal, national).

Furthermore, the sectorial insights outlined in Section 1.4 lead us to the assumption that although strategic decisions are being made at cantonal, and especially at national level, this is hardly reflected at all in infrastructure planning processes. Other studies have also shown the relevance or important decision-making power that local actors hold in water management (see Iglesias et al., 2011; Lubell and Fulton, 2007). And specifically in the urban water infrastructure sector, presumably driven by the predominance of a “technocratic scientific water management style” (van der Brugge et al., 2005), there seems to be a focus on short-term, operational objectives rather than on longer-term, strategic planning (Dominguez et al., 2009; Lienert et al., 2006; Truffer et al., 2010; van der Brugge et al., 2005). We thus hypothesize that the most influential stakeholders are local actors who follow restricted, local and short-term objectives:

H3a: Important stakeholders: Although many stakeholders play a role in infrastructure planning, the community engineer and local authorities are of primary importance.

H3b: Important stakeholders: Although cantonal and national stakeholders set strategic goals and are indispensable, local authority representatives are better integrated in the planning process.

H4: Represented interests: The interests of the main actors are typically of a shorter-term type, such as to “make a profit”, or “find a good technical solution” rather than longer-term sustainability objectives such as intergenerational equity and integrated catchment planning.

To test our hypotheses and make them more tangible, we follow a three-dimensional approach. First, we carry out a classical stakeholder analysis (Part I) to identify influential stakeholders and those affected by infrastructure planning (H3) and elicit their perceived main interests (H4). The stakeholder analysis serves to define the network boundary: in a second step, the cooperation relationships between relevant actors are assessed in detail by social network analysis. We investigate the actors' centrality and relational importance on the basis of the relational profile of every stakeholder. We have borrowed from the literature on multi-level governance and social networks to assess the horizontal (H1) and vertical integration (H2) of actors within water planning networks, and to test the importance of engineers (H3a) and local authorities (H3b). Third, we integrate an additional step into the stakeholder analysis (Part II) that asks respondents to identify elements of “ideal planning processes”, barriers to the current system and drivers used to overcome the perceived deficiencies. This step asks more holistically how stakeholders perceive the current structure in the water sector. It allows us to discuss in more depth what challenges should be addressed to meet sustainability and integration requirements in water management.

2. Material and methods

2.1. Case study

Our case study near Zürich is the focus of several research projects within the Swiss National Research Programme NRP 61 “Sustainable water management” (www.nfp61.ch). The rural region of “Mönchaltorfer

Aa" comprises four communities: Egg, Gossau, Grüningen, and Mönchaltorf near Lake Greifensee. The lake is used for leisure activities and includes some environmentally protected zones. There is considerable agriculture, but the proximity to Zürich also exposes it to pressure from urban growth. Lake Greifensee still suffers from phosphate eutrophication problems, with high inputs from agriculture and WWTPs (AWEL, 2003, 2006).⁴ Water governance is a typical example of Swiss fragmentation. Different entities own different parts of the water infrastructures. The population is served by several water suppliers and wastewater services, and the wastewater is treated in two WWTPs. The discharge reaches small rivers, and later Lake Greifensee (details in Supplementary Data; Tab. SD-A). The water quality in the rivers below the outlets of the WWTPs is insufficient and includes micropollutants (AWEL, 2006).

2.2. Selection of respondents; interview guideline

We used stratified sampling to select respondents (see e.g. Reed et al., 2009). We selected stakeholders along the vertical axis from local, via cantonal (authorities of Canton Zürich) to national level (authorities, associations of water professionals, science). We also selected stakeholders along the horizontal axis covering different sectors (engineering practice, administration & politics, general public, science). We included about equal numbers of representatives from all communities and both water sectors, and conducted two interviews with water supply engineers (not one) to balance the number of engineering actors (urban drainage, wastewater treatment, water supply). Additionally, we applied snowball sampling (Bortz and Döring, 2009) to include actors deemed important by respondents or to provide a new point of view. This applied especially to one engineer who contributed to the "water action plan" (AWEL, 2006). The representative of "communal infrastructures" answered only a few questions and did not feel that his organization influenced other actors. We excluded him from the stakeholder analysis, Part I and the network analysis, but included him in Part II (interview no. 27; see Supplementary Data).

We interviewed 27 actors. Most interviews lasted 2–2.5 hours, six 1.5–2h, and four 2h 40min–3.5h. They were digitally recorded; we took notes and transcribed the main points and sent these to the respondents for feedback. We followed a guideline with several main questions: Who is influential for and affected by planning, what are his/ her main interests (stakeholder analysis Part I)? Who interacts with whom and how (network analysis for cooperation relations)? What is required in addition to current infrastructure planning, what are barriers hindering and resources promoting good planning? Which factors are uncertain up to 2050 (stakeholder analysis, Part II)?

2.3. Stakeholder analysis

Stakeholders can be identified and classified on the basis of different approaches. The identification of stakeholders in particular is often an iterative process that draws on a rich variety of methods (e.g. expert opinions, focus groups, semi-structured interviews, snowball sampling, or any combination of these; e.g. Brugha and Varvasovszky, 2000; Reed et al., 2009). Analytical top-down or stakeholder-led bottom-up categorization can be used to differentiate between and categorize stakeholders (Reed et al., 2009). One typology is to classify them along the vertical axis, i.e. from global, national, regional, local, and off-site levels to a local, on-site level (termed the "Macro-Micro Continuum" by Grimble and Wellard, 1997). A further, and possibly the most fundamental division according to Grimble and Wellard (1997) "is likely to be between those who affect (determine) a decision or action, and those affected by this decision or action".

⁴ In summer, the oxygen content of the deeper water layers approaches 0 mg O₂/l, and fish cannot live there. If solar radiation increases the temperature of surface water layers, there is consequently a danger of fish death (AWEL, 2003).

To identify stakeholders, the respondents were asked to: 1.) mention all stakeholders who influence or are affected by water infrastructure planning; 2.) state their presumed main interest; 3.) quantify the influence each stakeholder exerts on water infrastructure planning using a visual Likert-type rating scale (Likert, 1932) with five equal intervals from 0 to 10 (0: “actor has no influence”; 2.5: “very small influence”; 5: “has influence”; 7.5: “strong influence”; 10: “actor decides about planning”; Brugha and Varvasovszky, 2000; see textbooks concerning rating scales, e.g. Bortz and Döring, 2009). They were also asked to 4.) quantify how much each is affected by planning (0: “not at all affected”; 2.5: “little”; 5: “affected”; 7.5: “strongly affected”; 10: “very strongly affected by planning results”). We merged very similar stakeholders (see Supplementary Data; Tab. SD-B). In case of different classifications, we assigned averages (e.g. perceived influence on a scale from 1–10). To characterize the stakeholders and test our hypotheses, we classified each stakeholder as follows: water sector (water supply (WS), wastewater (WW), both), decisional level (local, cantonal, national), sector (practice, administration & politics, public, science), sector details (engineers & industry; operators; administration WS; administration WW; administration others; politics; public; water associations; science), private or communal, and water interest (water use, protection, other). We also assigned an alleged interest (economic, technical, civil (societal), environmental) to each stakeholder, which is not necessarily the same as the interest assigned by the respondents (perceived interests). As an example, a similar (but simpler) sorting process was used in a recent meta-survey about stakeholder participation in 21 environmental research projects in the UK (Phillipson et al., 2012). Here, each project leader was asked to classify the participating stakeholders into the following categories: public, private, third sectors, and societal. We asked for the requirements of good planning, compared with today. Respondents classified each into: essential (“without this requirement good planning is impossible”); important (“difficult”); desirable (“planning is possible without”), and not significant. We repeated the procedure in order to record barriers and resources. We asked how barriers could be overcome, and about actors who could overcome barriers or provide existing resources. We asked what uncertain factors could influence the region up to 2050, and how worrying these were: -10 (very strongly worried) via 0 (neutral) to +10 (very strongly confident). Summary statistics and figures were produced in the R statistics and graphics software (<http://www.r-project.org>). For the influence on / being affected by infrastructure planning (scale 0–10), we calculated the average from all interviews in which the respective actor was rated. For the perceived stakeholder interests, requirements, barriers, resources and uncertainties, we calculated the total and average times they were mentioned in all interviews, or within groups.

2.4. Social network analysis

After identifying actors, the respondents glued a card for each actor onto a sheet of paper. These cards depicted relationships between actors with color-coded arrows for different relational types (cooperation, financial exchange, pressure, conflict). Similar “card-sorting procedures” have been used previously in the Swiss water sector to classify stakeholders into meaningful groups according to the criteria of the respondents (Pahl-Wostl and Hare, 2004). The method is actually derived from experimental psychology (see Pahl-Wostl and Hare, 2004 and references therein; Reed et al., 2009). Generally in stakeholder analyses, some sort of mapping procedure is often used as a second step to display an organization’s key relationships, or to display the strengths of relationships among stakeholders and the potential for coalitions (Brugha and Varvasovszky, 2000).

To test the hypotheses about the integration and structural fragmentation of actors developed here, we rely exclusively on the “cooperation network”. As shown in previous studies investigating local resource management projects and water policy (Hirschi, 2010; Ingold, 2013), cooperation relations seem

particularly relevant when studying the way that stakeholders involved in planning and implementation are organized. We also used attributes that characterize each actor as regards their horizontal or vertical affiliation, declared interests and perceived influence on / being affected by planning.

The data were analyzed in UCINET (Borgatti et al., 2002). The integration and potential influence of actors in a policy process can be assessed in network terms via its connectivity to others. One prominent concept is that of centrality developed by Freeman (1979). The structural importance of an actor is mostly assessed through degree centrality, which takes into account the ties that an actor shares directly with other actors. It looks at the local structure in which an actor is embedded (Ansell, 2003; Crona and Bodin, 2006). In policy networks, actors with high degree centrality have better and more direct access to information and have considerable potential for framing the planning process. In contrast, power and importance are usually assessed via betweenness centrality (Freeman, 1979; Ingold, 2011). Betweenness centrality calculates the number of times an actor is on the path between two not-interlinked nodes. It refers to the argument that an actor might be better integrated in a network if he or she links different partners who are not interlinked directly. An actor with high betweenness centrality can thus act as a gatekeeper or mediator; without him or her, the network would fall apart. Hence, the more central an actor is, the better he or she is integrated in the network and can influence the planning process in resource management policy.

We conducted a core / periphery analysis to account for the fragmentation of cooperation networks in infrastructure planning. A core consists of densely packed interlinked nodes and a periphery of nodes that are only (and loosely) connected to the center. Peripheral nodes are thus not well interconnected, and the network forms a star. The categorical core / periphery measure in UCINET is based on a fit function that operationalizes a correlation between the effective and permuted data matrix and the ideal-typical core / periphery function. This measure allows us to identify actors who have the structural potential to decisively influence infrastructure planning (core), and those who play a secondary role in this implementation process (periphery).

3. Results

3.1. Stakeholder analysis, Part I

The respondents mentioned 66 stakeholders who play a role in water infrastructure planning. They were merged to 41 main actors (see Methods; Supplementary Data; overview in Tab. 1).

<< Insert Table 1 about here >>

3.1.1. Influential and affected actors

A plot of the perceived influence of actors on infrastructure planning against how much they are likely to be affected by infrastructure decisions shows that most actors lie on the diagonal, i.e. the most influential actors are also most affected ones (Fig. 1; average of different interviews). For the sake of simplicity, we term actors that are both highly influential and strongly affected as “most important”. There are some exceptions; municipal fire departments (stakeholder (SH) 17) and landowners (SH 22) tend to be rather strongly affected, but have low decision-making power. Actors from the water supply and wastewater sector are distributed evenly from high to low importance with a slight tendency of those from the

wastewater sector (blue squares, Fig. 1A) to be somewhat more important than those from the water supply sector (red circles). Local actors were clearly more important in terms of decision-making level (red circles, Fig. 1B). Local actors were also mentioned more often than cantonal or national ones (larger symbols). Cantonal actors were perceived to be somewhat more influential for infrastructure planning, and as less affected (more blue squares lie in the top-left quadrant, Fig. 1B), while national actors were hardly influential at all, and only marginally affected (grey triangles in bottom-left quadrant, Fig. 1B). National and some cantonal actors mainly seemed to follow societal or environmental interests (bottom-left, Fig. 1C.), while local actors in particular were assigned to technical interests (blue squares, Fig. 1C, compare with Fig. 1B). Most actors assigned to economic interests (red circles, Fig. 1C) had little influence, and tended to be somewhat affected, with the exception of the local water supply (SH 1) and wastewater engineers (SH 2), who had a very high influence (also see Fig. 1D, dark-red circles). They were also mentioned very often (large size of symbols). Similarly, WWTP operators (SH 9, light-red circles, Fig. 1D) and the joint regional WWTP association (SH 12) were perceived to be very influential. Municipal politicians and managing boards (darker-green trapezoids, e.g. SH 14, 16, 19, Fig. 1D) also seemed to be influential, together with the municipal administration for wastewater (SH 15, medium-blue squares, Fig. 1D) and the wastewater sections of the cantonal agency for waste, water, energy and air (AWEL, SH 24 medium-blue square). The same institution in the water supply sector (AWEL) seemed to be less influential (SH 23, dark-blue square); this influential role seemed to be played more strongly by the cantonal laboratory and the association of cantonal chemists who are responsible for controlling drinking water quality (SH 25, light-blue square). Our own research institution, Eawag, was perceived to have no influence on planning (SH 40, 41, dark-grey triangle, Fig. 1D), while the two professional associations in the water supply (SVGW, SH 32, light-grey triangle) and wastewater sector (VSA, SH 33) do have some importance. Many more details can be read from these graphs (also see Supplementary Data; Fig. SD-A). As an example, most actors from administration and politics seemed to be quite important for water infrastructure planning, together with some practical actors (Supplementary Data, Fig. SD-AA); while citizens and tourists (SH 21) as the main representatives of “the public” seemed to be of medium importance. As regards “water interest”, the most important stakeholders can be assigned to “water use”, while those stakeholders focusing on “water protection” had somewhat less influence on planning, and were considerably less affected (Fig. SD-AB). Finally, communal actors seemed more important than private ones (Fig. SD-AC).

<< Insert Figure 1 about here >>

3.1.2. Main interests

We assigned the perceived interests of each stakeholder with shared features to one of eight main categories: economic, planning, technical, management & operation, legal, environmental, and societal (see Supplementary Data). Because the same stakeholders were assessed by different respondents, as a rule one stakeholder had several “main” interests. In all interviews, 402 interests were assigned to the different players. By far the largest majority concerned economic interests, mentioned 114 times. Next most often mentioned were technical aspects (68x) and interests in water infrastructure services (67x; details Supplementary Data, Tab. SD-D). Below, we present the most important results concerning actor groups; the average number of times an interest was mentioned per stakeholder group is given in parentheses.

Both water sectors, namely the water supply (WS; 2.37) and wastewater (WW) sector (3.58), were perceived to follow mainly economic interests, followed by infrastructure services for WS (1.68, WW: 1.17)

and technical interests for WW (2.5, WS: 1.42). The WW sector was also perceived to follow legal interests (1.67, WS: 1.26), while other interests were mentioned less than once on average per stakeholder group. Regarding the decisional level, economic interests were very prominently assigned to local stakeholders (5.05), followed by technical interests (2.91), and infrastructure services (2.27). In contrast, cantonal actors were perceived to follow legal interests (2.56), followed by environmental interests (1.78), and infrastructure services (1.44). The same pattern applied to national actors, but was mentioned less often.

Concerning the sector, practical actors were perceived most often to follow economic interests (3.80), especially the engineers and industry (6.29), while operators were most often perceived to have technical interests (3.20), which also seemed important for engineers and industry (3.43). The administration and political sectors were also perceived to prioritize economic interests (2.0), followed by legal interests and infrastructure services (both 1.71). However, closer examination of the water sector revealed that legal interests were perceived to be most important by far for the administration of water supply (4.0) and wastewater (4.33), while “other” administrative bodies were strongly assigned to interests in the infrastructure services (1.22). Politicians were seen to have mainly economic interests (4.50), but also interests in societal aspects as well as infrastructure services (both 2.67). The public was also perceived to have strong interests in infrastructure services (5.33) followed by economic interests (4.67). The same patterns applied to the private and communal sector, economic interests being perceived as most important (private: 6.44, communal: 1.75), followed by technical interests for the private sector (3.11; communal: 1.25), and infrastructure services for the communal sector (1.53, private: 2.0).

Moreover, economic interests were most important for actors assigned to “water use” (3.89) and “others” (1.75), while those in “water protection” were perceived to have mainly legal (1.80) and environmental (1.30) interests. The “other” actors also had relatively high societal interests (1.50). “Water use” actors had high technology-related interests (2.33) as well as interests in infrastructure services (2.22). Finally, there was good coherence between our assignment to interests and the perceived interests of the respondents (Tab. SD-D).

3.2. Network analysis

We display the overall cooperation networks identifying actors with reference to 1.) the water sector they belong to; 2.) the decisional level they represent; and 3.) the core interests they defend. Figure 2 highlights the water sector to which each actor belongs. The result is very clear: actors belonging to the same sector tend to show more mutual cooperation. The infrastructure planning process is clearly fragmented into three clusters; actors representing wastewater hardly interact with those belonging to the water supply sector and vice-versa. The size of the node indicates an actor’s betweenness centrality; few actors have the capacity to link stakeholders who would not be interconnected without their presence. The wastewater sections of the cantonal agency for waste, water, energy and air (WW cant. agency AWEL; SH 24; Tab. 1) as well as the municipal managing boards for aboveground engineering, utilities, and finance (Munic. engin., utilities, finance; SH 19) are good mediators and gatekeepers displaying a high betweenness centrality. This is a further indicator that local actors play a central role. As expected, local engineers (WW and WS local engineer, SH 1, 3) play quite a central role by sharing many ties with others; they have a reasonably high degree centrality (Fig. 2; also see Supplementary Data, Tab. SD-C). However, these collaborations primarily take place within their specific water sector.

<< Insert Figure 2 about here >>

Lienert, Schnetzer, Ingold (2013) Stakeholder analysis combined with social network analysis provides fine-grained insights into water infrastructure planning processes. *Journal of Environmental Management* 125: 134-148.

An analysis of the same cooperation network, but now referred to the decisional level of each actor, shows that it seems largely dominated by local actors (in red, Fig. 3). The second largest group is formed by the cantonal representatives (blue nodes). National actors are very sparsely represented (in black), they are also very peripheral, or even outside the network (listed top-left), and not at all central.

<< Insert Figure 3 about here >>

Furthermore, environmental interests (grey nodes, Fig. 4) are rather peripheral in the same cooperation network, with one exception: the very central actor representing the wastewater sections of the cantonal agency for waste, water, energy and air (WW cant. agency AWEL; SH 24). All interests, but mostly economic ones (red nodes), seem represented in the wastewater and water supply sectors (compare with Fig. 2). Civil interests are in general well represented, but mainly through the presence of the municipal managing boards for aboveground engineering, utilities, and finance (Munic. engin., utilities, finance; SH 19; largest black node).

<< Insert Figure 4 about here >>

Details of the centrality measures for every actor are given in the Supplementary Data (Tab. SD-C). This also illustrates that mostly local actors and engineers participate in the core. Cantonal and all national actors are peripheral in this process. Among the most central actors we can identify wastewater as well as water supply representatives. Additionally, we analyzed the cooperation network for the sector to which an actor belongs (Supplementary Data, Fig. SD-B), the influence each actor has on planning (Fig. SD-C), and how much he is affected by planning (Fig. SD-D).

3.2. Stakeholder analysis, Part II

3.2.1. Ideal planning, barriers and resources

We assigned statements about (A) additional requirements to optimize current planning, (B) barriers that hinder, and (C) resources that support good planning to nine groups: 1. economic; 2. planning; 3. technical; 4. management & operation; 5. legal; 6. political; 7. environmental; 8. societal; 9. education & research; 10. everything OK; 11. no comment (details Supplementary Data, Tab. SD-E). (A) The majority of requirements were assigned to planning aspects, mentioned 18 times over all 27 interviews, with equal distributions between efficiency, catchment planning and horizontal collaboration. Vertical collaboration was mentioned once (Tab. 2). Management & operation (12x) and technical aspects (11x) were mentioned often, followed by economic requirements (9x). (B) Economic topics were also perceived as barriers (12x), especially a lack of money, followed by political barriers (10x), mainly deficiencies of the political system, e.g. coupling of local politics with planning, lack of continuity (elections every four years), or political favoritism (knowing the politician helps in obtaining a planning mandate). Planning barriers, especially lack of integrated catchment planning and horizontal integration were mentioned in one third of the interviews. (C) Resources were most often assigned to management & operation (21x), and current planning was perceived as professional by 18 respondents. Other important resources were technical (19x), especially a good database. Despite deficiencies, current planning was also perceived as a resource (12x), especially aspects of horizontal collaboration (e.g. engineers with community) and vertical collaboration (i.e. support of community planning by cantonal authorities). Eight respondents saw finances as a resource, although this was perceived as a barrier by about the same number of respondents. Six

respondents identified resources in education & research, especially practical education, which was hardly mentioned for requirements and barriers. Furthermore, political, legal, and societal aspects were mentioned by some respondents. The environment received little attention, three respondents mentioned a lacking of sustainability considerations in planning, and two saw the water from Lake Zürich as a resource. We also analyzed differences between stakeholder groups (for reasons of space, see Supplementary data; Tab. SD-F).

<< Insert Table 2 about here >>

3.2.2. Stakeholders who can overcome barriers or provide resources

Most stakeholders who could overcome barriers (61x mentioned in total) or provide resources (136x) were local (barriers: 30x; resources: 100x). However, cantonal (11x) and national actors (18x) were also mentioned often, especially for barriers (Supplementary Data; Tab. SD-G). Communal authorities, including local politicians, were perceived to be capable of overcoming barriers (mentioned 18x for 7 of 9 topics). The community was also perceived to possess resources (32x), along with engineers (27x). Engineers were seen in particular to possess resources in professional management (12x) and technology (good database; 6x). Commercial relations with engineers (a management aspect) and horizontal collaboration (e.g. engineer with community; a planning aspect) were mentioned 3x. The water supply and joint regional associations for wastewater treatment provide substantial resources (20x), also as regards professional management (7x) and good data (6x). One regional water supplier (GWVZO) seemed especially important (mentioned alone 5x). The general population was rarely perceived to be in a position to overcome barriers (3x), but to provide some resources (9x), for societal topics (awareness and participation, both 2x), and additional financing (4x).

The cantonal agency for waste, water, energy and air (AWEL) was perceived to be capable of overcoming barriers (7x), e.g. with integrated catchment planning. AWEL was seen as even more important as a provider of resources (10x), especially for vertical collaboration; i.e. controlling and supporting communal planning (3x). AWEL was also seen to have competencies in technology (data; 2x) and professional management (3x). Along with politicians, cantonal authorities seemed able to overcome financial barriers (both 3x). At national level, the two associations of water professionals were mentioned most often (barriers: 5x, resources 6x), especially concerning resources in practical education (3x). National authorities were mentioned 3x in the context of overcoming financial barriers. Not surprisingly, all politicians were seen to be helpful in overcoming political barriers (3x), but were also mentioned in legal and societal contexts (5x total). Our own research institute, Eawag, was mentioned a few times. Four new actors were introduced; e.g. the media were seen as an agency that could help raise awareness about the importance of water infrastructures.

3.2.3. Suggestions for overcoming barriers

Raising water tariffs and wastewater bills or receiving subventions from cantonal or national authorities were seen as ways to overcome (1.) economic barriers (Supplementary Data, Tab. SD-H). This requires political support and greater awareness among the population (7. societal barrier), a task assigned to the media, Eawag, and associations of water professionals. Professional financial planning by communities could also prove effective. To deal with a lack of personnel, foreign engineers could be recruited. Professionalization would help overcome (2.) planning barriers, including better horizontal collaboration,

as well as regional planning at catchment level – and in extreme cases the assignment of functional spaces by national authorities. This may require new laws, a task for the cantonal authorities and politicians. Education and terms of reference would be needed, to be provided by associations of water professionals. To overcome (3.) *technical* barriers, data and software would need to be harmonized, including automatic registration of all communal data. Industrial and research projects would be required, funded e.g. by the Swiss National Science Foundation (a new actor). Internationalization and an open market could be promoted by national authorities. Increased professionalization, less bureaucracy, and similar measures were perceived as ways to overcome existing (4.) *management & operational* deficits at communal and treatment plant level. Education of engineers is also needed, a task for associations of water professionals. The public procurement procedure is a given (5.) *legal* barrier and requires changes in the law. However, it would help if the community had transparent procurement and tender procedures and set quality standards. (6.) *Political* barriers do not seem easy to overcome; political discontinuity would only change if planning responsibility was decoupled from local politics. One suggestion was to give operators more (financial) competencies. Generally, politicians should pursue more long-term thinking. To overcome (7.) *environmental* barriers (lacking sustainability concepts, no priority for water protection), more control is required by the cantonal authorities; communities should include sustainability in planning. Eawag was asked to recommend new organizational structures that emphasize environmental aspects, and associations of water professionals should put these into practice. These two actors could also overcome barriers in *education & research* by carrying out interdisciplinary (practice-relevant) environmental engineering studies.

3.2.4. Future uncertainties

Most respondents (20 of 27) perceived climate change as an uncertain future factor that would affect water infrastructures, including melting of glaciers, droughts and reduced availability of water resources, as well as extreme rainfall (details Supplementary Data, Tab. SD-I). This was followed by demographic changes such as population growth, spatial planning including urban sprawl, and economic topics such as a lack of finances for water infrastructures (mentioned 16 / 16 / 15 times). Other topics were mentioned less often: the development of water consumption and water price (10x), various technical developments for water and wastewater treatment and precise measurements (8x), water quality and emerging (micro-)pollutants (7x), changes in organizational & political structures up to privatization (6x), energy and nutrient recycling from wastewater (5x), new legislation (4x), and terrorism (1x). Most respondents (23) felt quite confident about the future, only six stakeholders perceived these aspects as worrying and having negative effects on water infrastructures.

4. Discussion

4.1. Horizontal and vertical fragmentation

The network analysis clearly showed that the fragmentation of the Swiss water sector is indeed reflected in a typical water infrastructure planning processes in a region near Zürich. This is very much in line with former Swiss studies about local resource management and natural hazard prevention (Hirschi, 2010; Ingold, 2013). As hypothesized (H1), and confirming statements in the literature (e.g. Daigger, 2009; Konrad et al., 2008), there is little collaboration between the wastewater and water supply sectors (Fig. 2). Systematic collaboration between local actors is not very strong (Fig. 3); local actors dominate

collaboration in this process, but are also distributed over half of the network, with only loose ties between many actors. The same applies to cantonal actors spread over parts of the network, and especially to the few national actors distributed around the periphery with hardly any direct interlinkages. Moreover, central and well-connected actors come from practice and administration & politics (Supplementary Data; Fig. SD-B). Here, we did find indications of collaboration across sectors, especially between some local practice actors and cantonal agencies. However, there were few links between science and the public to water infrastructure planning, and very few direct links between different authorities, confirming horizontal fragmentation between and within sectors.

Second, under the hypothesis of vertical fragmentation (H2), we expected to find little collaboration between local, cantonal, and national decision levels. We found that all actors in the core of the network are local (engineers and authorities), except three cantonal players (Fig. 3; Tab. SD-C). The network links of the local actors are predominantly to other local actors, with very few connections across decision levels (i.e. to cantonal or national actors; Figs. 3, SD-D), confirming vertical fragmentation. However, one local stakeholder (SH) plays a central role (high betweenness centrality): the municipal managing boards for aboveground engineering, utilities, and finance (SH 19; Tab. 1). These local authorities can thus bridge the gap between the two water sectors. This was already laid out in a former study paying special attention to authorities and their capacity to link actors and levels in national and international climate policy (see Ingold and Pflieger, 2013). It is not surprising that mainly local actors can play this gate-keeping role between levels in this context: not only in Switzerland, but also in other countries, water management and planning seems predominantly organized through local stakeholders (Iglesias et al., 2011; Lubell and Fulton, 2007).

Furthermore, the central role played by local engineers was confirmed by their high degree centrality with many links to other actors (Fig. SD-D), but predominantly within their respective water sector and decision level. One actor clearly exhibits a strongly integrative role across all decision levels, forming links between local, cantonal, and some national actors (Fig. 3) in contrast to the hypothesis of vertical fragmentation, namely the wastewater sections of the cantonal agency for waste, water, energy and air (AWEL; SH 24). Hence, the network analysis helped to confirm the fragmentation of the water sector, but also to pinpoint where, contrary to expectations, integration across sectors and decisional levels does exist, mainly due to the very few actors holding the network together. To our knowledge, this has not yet been formally analyzed for water infrastructure planning, although the fragmented governance of the Swiss water sector is “general knowledge” (e.g. Dominguez et al., 2009; Lienert et al., 2006). The divide between water supply and wastewater is typical of many countries (Konrad et al., 2008), with the notable exception of England and Wales (Bakker, 2003, 2005; Guy 1997).⁵ Separated regimes are also characteristic for other network-bound infrastructure systems such as the electricity, gas, and telecommunications sectors. The German water provision and wastewater disposal sector, for example, involves many different institutional and technical structures, including different professional cultures, professional associations, and even different attitudes towards “water” (Konrad et al., 2008). This “stove-piping” within the water sector, i.e. the separate management of water supply, storm water, and wastewater, has been heavily criticized by water professionals (e.g. Daigger, 2009). In the Swiss water sector, recent strategic planning exercises have clearly identified the necessity to overcome fragmentation with some sort of horizontal, vertical, or

⁵ The water sector in England and Wales has undergone a very different development than most other European countries. Following privatization (see e.g. Guy, 1997), water companies faced the difficulty of ensuring sustained profits in the mature, regulated, low-growth water sector (Bakker, 2003). Some utilities then pursued a strategy of horizontal integration by creating multi-utilities (electricity, gas, water, and telecommunications), or pursuing joint ventures. As Bakker (2003, 2005) shows, the British privatization model combined with regulatory constraints posed serious threats to the economic viability of the private utilities. This recently led to a period of re-structuring, including vertical de-integration: instead of providing the entire cycle of water services to customers (from water extraction via delivery to treatment and discharge of wastewater), some utilities are separating asset ownership from operation and maintenance, while others propose returning water supply infrastructures to public control, e.g. through corporations (as is a common model in Switzerland).

geographical integration (Dominguez et al., 2009⁶; Lienert et al., 2006; Truffer et al., 2010⁷). However, not only strategic planning, but new phenomena are also creating a push to link water supply and sanitation. In Germany, for example, water consumption has decreased substantially due to the socio-political changes in Eastern Germany and generally reduced per-capita water consumption (Konrad et al., 2008). Bringing water into settlements, however, is tightly linked to draining wastewater out, and changes to one part of the system, e.g. by decentralization or water recycling, inevitably affect the other.

4.2. Important stakeholders

In the Swiss water sector, far-reaching decisions are typically made by national or cantonal bodies. A topical example is the proposition by the Federal Office for the Environment (FOEN, 2012) to upgrade 100 of the largest wastewater treatment plants with a fourth treatment step to approximately halve micropollutants in water bodies. This requires total investments of CHF 1.2 billion (CHF 60m yr⁻¹). Currently, a mix of subsidies and the polluter-pays principle is proposed by the Swiss Federal Council. The required change in the water protection law was under political consultation (until 31.08.2012). The decision as to which smaller WWTP should be upgraded is delegated to the cantonal authorities (in Zürich: AWEL). However, Part I of the stakeholder analysis hardly mirrored this political reality at all, even though it affects water infrastructures directly.

A total of 66 stakeholders were mentioned as playing a role in local planning procedures (merged to 41 main actors). Local actors are clearly dominant (Figs. 1B, 3), thus confirming our hypothesis (H3a; also see Iglesias et al., 2011; Lubell and Fulton, 2007). The high influence of local engineers on the planning process (SH 1, 2; Fig. 1D) was confirmed in the stakeholder analysis (Part I) and the social network analysis. Other highly influential stakeholders are the WWTP association and operators, as well as municipal politicians and administrations (Fig. 1D). Some cantonal actors have quite a strong influence on planning, namely the wastewater sections of AWEL (SH 24, Fig. 1D), thus confirming the results of the network analysis. In the water supply sector, this mediating role is also played by AWEL, but especially by the cantonal laboratory and the association of chemists, who control the quality of the drinking water (SH 25, Fig. 1D). As expected (H3b), most cantonal actors, and especially the national ones, were perceived as marginal in both the stakeholder analysis (Part I) and the social network analysis.

In Europe, major transitions are taking place in the water and other infrastructure sectors, and these are being analyzed by a growing body of literature (e.g. Bakker, 2003, 2005; Guy 1997; Konrad et al., 2008; Moss, 2009; van der Brugge et al, 2005; for a recent review of sustainability transitions, see Markard et al., 2012). However, a recent analysis of the governance of the water and energy services in Europe criticized the infrequent acknowledgement that this transition leads to new tasks to be performed by new actors: there seems to be little focus on actors who cannot be categorized as providers, users or regulators (Moss, 2009). Our first results are fully in line with this observation, and only our additional questions were able to identify other actors who may play an important role in longer-term, sustainable water planning (see Section 4.4).

⁶ The result of a strategic planning exercise for the city of Bern, which had previously already pursued a growth strategy, was “to expand its strategy range along the dimension of ‘new business fields’ by considering the operation of communal and non-communal satellite plants. Kloten-Opfikon decided to pursue a geographical growth strategy. The strategy aims at integrating several neighboring wastewater treatment organizations and the corresponding sewer networks into one organization that provides a wastewater treatment service for a larger region. By contrast, Dübendorf decided to expand along the dimension of vertical integration” (Dominguez et al., 2009).

⁷ For the Swiss region of Klettgau, near the German border, the stakeholders of a strategic planning exercise preferred the option of “removing the regional WWTP and connecting the sewers to a larger plant in Germany”, i.e. to “extend the system boundaries beyond the national borders to Germany” (Truffer et al., 2010).

4.3. Represented interests

We had hypothesized (H4) that the interests of the main actors would typically concern shorter-term rather than long-term sustainability goals. Indeed, as an example, intergenerational equity was not even mentioned, although infrastructure planning today will certainly affect future generations due to the longevity of the components used, and intergenerational equity is a core objective of sustainable development (discussion of the concepts in Wuelser et al., 2012). The focus on shorter-term objectives was confirmed in both the stakeholder and network analyses, and is very much in line with former studies (see Ingold, 2013) that outlined the priority accorded by stakeholders to short-term benefits, rather than long-term territorial planning strategies in natural hazard prevention. This is also in line with the results of the strategic planning exercises in the Swiss water sector already mentioned (Dominguez et al., 2009; Lienert et al., 2006; Truffer et al., 2010). All interests in both water sectors seem represented in the social network, with economic and technical interests being central (Fig. 4). However, civic societal interests also seem important, mainly due to the centrality of the municipal authorities. Environmental interests seem peripheral, with the exception of their main carrier, the cantonal authority AWEL.

The stakeholder analysis provided more details. By far the greatest number of interests as perceived by respondents could be assigned to economic topics (mentioned 114 times; see Results and Supplementary Data, Tab. SD-D). About half as many assignments concerned the technology and water infrastructure services. This is not surprising since the central engineers ultimately fulfill a mandate to earn money, and the operators of treatment plants, for instance, want the technology to work. Many other actors, including politicians and the public, were perceived to be strongly interested in receiving services from the system. This is plausible; it is, after all, the reason for putting the infrastructure in place. This pattern applied strongly to local actors, while cantonal and national actors primarily follow legal and environmental interests. This confirms our assumption that strategic goals are pursued on higher decision levels (H3b). Legal interests were assigned more often to wastewater, but not to water supply actors (with the exception of local administrations). This may reflect the discussions on the removal of micropollutants, which affect the wastewater sector (FOEN, 2012). Societal aspects seem less important and were attributed mainly to politicians. These, however, seem most strongly interested in economic aspects, including low wastewater fees. Hardly any importance was placed on planning aspects, including strategic and integrated catchment planning. This picture is turned upside down in the stakeholder analysis, Part II, below. In line with our results, van der Brugge et al. (2005) postulate that the water management regime in the Netherlands is currently in a transition stage from a “technocratic scientific water management style” towards an integral and participatory style, but that this process can get stuck because of severe incompatibilities between the strategic and operational levels of water management.

4.4. Sustainable and integrated catchment planning

Part II goes beyond typical stakeholder analysis questions (e.g. Brugha and Varvasovszky, 2000; Grimble and Wellard, 1997; Reed et al., 2009). We reached our goal of opening minds by asking about the requirements of ideal planning, resources that support good planning and barriers that hinder it. Technical, management and operational topics were generally perceived as good, or easily addressable, e.g. with up-to-date technologies including harmonized software and automatic data registration (Olsson, 2012). However, many respondents now also discussed catchment planning, collaboration across sectors and the political system (see Results, Tab. 2; Supplementary Data, Tables SD-E–SD-H). Economic barriers

were mentioned in nearly half of the interviews, but were not seen as insurmountable: in richer OECD countries, water bills can be raised or state subventions granted. The first measure is not unrealistic: the willingness of the Swiss population to pay for upgrading wastewater infrastructures in response to climate change equals their current bills (Veronesi et al., 2013).⁸ Subventions have re-entered the political discussion with the proposal to upgrade WWTPs to remove micropollutants (FOEN, 2012). The respondents were aware that previously peripheral actors such as politicians are needed to overcome economic barriers and general drawbacks of the current system, including the public procurement by tender procedure. As an example, awareness should be raised among the population, with help of the media, our research institute and the Swiss associations of wastewater professionals. This corresponds to the observation already noted that the public service-oriented utilities are in a transition phase, and are under particular pressure with respect to their economic efficiency (e.g. Bakker, 2003, 2005; Guy 1997; Konrad et al., 2008; Markard et al., 2012; Moss, 2009; van der Brugge et al, 2005). New actors are entering the field, termed “intermediaries” by Moss (2009), because they bridge gaps by facilitating dialogue or advocating reform. They include business consultants, researchers who translate new environmental legislation into practice and nonprofit agencies (ibid). In our Swiss case, apparently marginal actors, including the population and media, politicians, professional associations and our own research institute may play important roles when longer-term sustainability aspects are introduced to water management.

Furthermore, we found that greater continuity in infrastructure planning can also be achieved by decoupling local politics from infrastructure planning. Both aspects require political and legal system changes and also indicate that Switzerland is on the brink of entering the transition phase. Finally, one third of respondents mentioned the lack of integrated catchment planning and cross-sectorial collaboration. While we already detected this behavior, our new questions actually allowed respondents to observe this drawback themselves and suggest solutions. In Switzerland, local communities have a very strong voice (reflected in the network). Hence, it is rather extreme to suggest that national bodies could carry out regional planning and assign functional spaces that cross community (and cantonal) borders. Again, politicians and authorities at high decision levels could adequately address this concern by changing the law. In line with these results, integrated water resources management (IWRM) is being advocated to address the many challenges in the water sector, but it is also criticized because its implementation is proving difficult (e.g. Biswas, 2004; van der Brugge and Rotmans, 2007). Presumably, a pragmatic, case- and site-specific approach to integrated water resources management that may vary widely between countries is most appropriate (e.g. Hering and Ingold, 2012; Molle, 2009).

5. Conclusions

We hope to have demonstrated that a combination of a classical stakeholder analysis (Part I), including rarely asked questions (Part II) and the rigorous approach of social network analysis is very fruitful. Each of them generated complimentary results and helped us to better understand the social system under scrutiny: the political-engineering world of water infrastructure planning. Stakeholder analyses typically ask who is important in policy processes and who is affected by (water planning) decisions (e.g. Brugha and Varvasovszky, 2000; Grimble and Wellard, 1997; Reed et al., 2009). Although a large number of

⁸ Today, a Swiss household pays around CHF 75–250 annually in wastewater taxes. In a representative population survey, respondents were willing to pay on average a local tax increase of CHF 240 person⁻¹ year⁻¹; Veronesi et al., 2013.

actors were mentioned, even haphazardly, a careful analysis revealed initial patterns. The stakeholder analysis showed the clear dominance of local actors, namely engineers, while cantonal and especially national actors were perceived as less important. We then verified the hypothesis that the main actors follow shorter-term interests. We found that the stakeholder analysis provided more insight into this question than the network analysis. In the latter, we analyzed interests that we assigned to each actor, which generated a fairly even spread, with less emphasis on economic objectives. In contrast, the open questions of the stakeholder analysis, which asked the respondents for their perceptions, revealed strong interests in economics, technology and water infrastructure services. Hence, the more qualitative approach provided more fine-grained insights than our own categorization. Reed et al. (2009) review this sensitive issue. There are obviously merits and drawbacks to both analytical and bottom-up categorizations based on stakeholder perceptions.

The social network analysis, which requires more rigorous data collection, also yields more accurate results. We found it very useful to consolidate the initial patterns from the stakeholder analyses and to test some hypotheses. As an example, the network analysis allowed us to easily identify the fragmentation of the Swiss water supply and wastewater sector (and others), and the fragmentation between decisional levels. These results thus confirm that social networks can depict how actors actually behave in planning processes (Bodin and Crona, 2009). A next step would consist in linking these network structures to the effective outputs of the processes to determine if the networks can impact social learning among actors (see Newig et al., 2010).

Our additional questions went a step further than the usual stakeholder analysis and investigated to what extent the actors themselves realize the shortcomings of their system. Many respondents were fully aware that integrated catchment planning is an imminent necessity, and that the water sector is in dire need of better collaboration to increase efficiency and overcome the drawbacks of fragmentation. They were aware that current infrastructure planning can hardly meet longer-term sustainability challenges if it is so closely coupled with local politics. Like other public utilities in Europe (e.g. Bakker, 2003, 2005; Guy 1997; Konrad et al., 2008; Markard et al., 2012; Moss, 2009; van der Brugge et al, 2005), the Swiss water sector seems to be in a transition phase. Observations from the Netherlands (van der Brugge et al., 2005) are also likely to apply to Switzerland: at strategic level, concepts of the new water management style seem broadly shared, while numerous practical questions remain open at operational level. Managing this transition thus requires a joint learning process and successful organization of a multi-level governance model to support communications between three levels of scale: the strategic level, the tactical level, which develops joint agendas and spreads new ideas, and the operational level. An interactive and participatory management process with a long-term focus, including uncertainty, is required to integrate different perspectives of the stakeholders (van der Brugge et al., 2005). In our example, most stakeholders already perceived climate change as an important factor that adds to the uncertainty of infrastructure planning up to 2050, along with population growth that affects spatial planning, and financial pressure. These major evolutions will certainly affect the institutional setting of infrastructure management and planning and impact the design of measures and stakeholder participation during the next few decades (Gerber et al., 2009; Rauschmayer et al., 2009).

Better understanding of the complex interactions and interests of stakeholders is often a starting point of environmental policy planning, and is followed by more quantitative decision-making or planning steps (see e.g. Renn et al., 1993; for water resources planning e.g. Keller et al., 2010; Starkl et al., 2009, and for marine planning Maguire et al., 2012). In our case, the follow-up is a formalized multi-criteria decision analysis that includes the goals and subjective views of the stakeholders (selected with the help of this paper), and we are combining it with scenario planning to grasp future uncertainty (the MCDA approach is outlined in Lienert et al., 2013).

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To conclude, a combination of qualitative and more quantitative approaches provides the best insight into stakeholder processes. Including unconventional questions helps to open minds to consider new approaches and invites new actors to the scenario. The case of water infrastructure planning demonstrated that it is inadequate to delegate this vital system to engineers alone. If we want to meet the challenges of the next decades, we need to think about unconventional solutions at all levels. We need politicians to discuss which regulatory guidelines are best suited, we need the media and the population to be interested in how their water is provided and their wastewater discharged, we need water professionals to discuss sustainability and push new goals into practice, and we presumably also need scientists like ourselves to develop creative ideas for the world of tomorrow.

Supplementary Data

Supplementary Data containing details about the study region, the stakeholder characteristics, the stakeholder analysis Parts I and II, and the network analysis, are available alongside the electronic version of this article in Elsevier Web products, including ScienceDirect: <http://www.sciencedirect.com>.

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Figures and Tables for main text

Table 1. Stakeholders playing a role in water infrastructure planning. Stakeholders are grouped according to their decisional level: local, cantonal, and national actors; the respective stakeholder numbers 1–41 are used in the text. WS: water supply; WW: wastewater; WWTP: wastewater treatment plant; for more details, see Supplementary Data (Tab-SD-B).

Local (practice)	Local (administration & politics)	Cantonal	National
1 WS local engineer	13 WS municipal administration for water supply	23 WS cant. agency for waste, water, energy and air (AWEL, water supply)	32 WS Swiss association of gas and water professionals SVGW
2 WW local engineer (urban drainage, WWTP)	14 WS municipal managing board for underground engineering, water supply	24 WW cant. agency for waste, water, energy and air (AWEL, wastewater)	33 WW Swiss association of wastewater & water protection professionals VSA, communal infrastructure association
3 WS local planning consultant (community engineer, hydro-geologist)	15 WW municipal administration for wastewater	25 WS cant. agency for drinking water quality (cant. laboratory, assoc. cant. chemists VKCS)	34 Swiss network of actors in the water sector "Water-Agenda 21"
4 WW local planning consultant (urban drainage, WWTP planning engineer)	16 WW municipal managing board for underground engineering, wastewater	26 WS cant. office for landscape & nature ALN (dept. agriculture) & office for melioration	35 WS Federal office for the environment FOEN, groundwater protection section
5 WS industry (water equipment manufacturers, industry consumers)	17 WS municipal fire department	27 WS cant. insurance on buildings GVZ (fire)	36 WW Federal office for the environment FOEN, quality of surface waters section
6 WW sewer maintenance companies	18 WS municipal managing board for health	28 WW cant. office for landscape & nature ALN (dept. hunting & fisheries)	37 WS Federal office of public health FOPH
7 Other utilities (electricity, telecommunications, construction companies)	19 Municipal managing boards for aboveground engineering, utilities, finance	29 Cant. office for underground engineering	38 WS Federal office for agriculture FOAG
8 WS operating staff & emergency response team	20 Municipal politicians (municipal council, municipal assembly)	30 Cant. office for spatial development ARE	39 Non-Governmental Organizations NGOs
9 WW operating staff (urban drainage, WWTP)	21 Citizens, tourists	31 Cantonal council (politicians, "Regierungsrat")	40 WS Swiss federal institute of aquatic science and technology Eawag (water supply)
10 WS regional water supplier (GWVZO)	22 Landowners, real estate companies		41 WW Swiss fed. inst. aquatic sci. & tech. Eawag (wastewater)
11 WS regional water supplier (regional cooperative)			
12 WW joint regional WWTP association			

Figure captions

- Figure 1. Perceived mean influence on and being affected by water infrastructure planning.** Scale from 0 (“actor has no influence/ is not at all affected”) to 10 (“actor decides/ is very strongly affected by planning results”), grouped according to the water sector (A), decisional level (B), assigned interests (C), and further sector details (D). The size of the symbols is proportional to the times an actor was mentioned across different interviews. The actors are numbered (see Tab. 1). WS: water supply; WW: wastewater; WWTP: wastewater treatment plant; for more details, see Supplementary Data.
- Figure 2. Cooperation network by water sector.** Red nodes indicate actors belonging to the water supply sector (WS), blue nodes actors representing the wastewater sector (WW), and black nodes actors who represent both water sectors. Actors not participating in the network are listed top-left. The size of the node indicates an actor's betweenness centrality (see text and Supplementary Data, Tab. SD-C; for details concerning actors, see Tab. 1).
- Figure 3. Cooperation network by decisional level.** Red nodes indicate local actors, blue nodes cantonal ones, and black nodes national ones. Actors not participating in the network are listed top-left. The size of the node indicates an actor's betweenness centrality (see text and Supplementary Data, Tab. SD-C; for details concerning actors, see Tab. 1).
- Figure 4. Cooperation network by interest.** Red nodes indicate actors that we assigned to having economic interests, blue nodes technical ones, grey nodes environmental ones, and black nodes civil ones. Actors not participating in the network are listed top-left. The size of the node indicates an actor's betweenness centrality (see text and Supplementary Data, Tab. SD-C; for details concerning actors, see Tab. 1).

Table 2. Additional requirements to current planning in the water sector to make it an ideal process, barriers that hinder, and resources that support good planning. Summary of statements from 27 stakeholder interviews, classified according to nine main topics. For the sub-topics, see text and Supplementary Data. Ct: count = total number of times the respective sub-topic was mentioned (per requirement/ barrier/ resource); Aver. import.: average importance of the respective requirement/ barrier/ resource assessed on a scale of 1 (requirement/ barrier/ resource is not significant) to 4 (... is essential); OK: "everything is fine as it is" (no additional requirements needed, no barriers); no com.: respondent was unable to make a statement about this topic; NA: not applicable.

	1. Economic		2. Planning				3. Technical				4. Management & operation			5. Legal			6. Political		7. Environ.	8. Societal		9. Educ. & research		OK	No com.
	Mon-ey	Per-sonn	Effic	Cat-chm	Horiz	Vert	Data	Tools	Infra-str	Equ-ipm	Har-mon	Com-rel	Prof-ess	Com-pl	Reg-ul	Com-pet	Syst	Supp		Partic	Awa-re	Pract	Sci		
	11	12	21	22	23	24	31	32	33	34	41	42	43	51	52	53	61	62	7	81	82	91	92	10	NA
Ct. requirements	6	3	6	5	6	1	3	6	2	0	2	1	9	1	1	3	4	2	0	3	0	1	0	1	1
Aver. import.	3.3	2.0	2.7	2.8	2.8	3.0	3.7	2.9	2.5		3.0	3.0	3.2	3	2.0	2.3	3.0	2.0		3.0		3.0		3.0	
Sum requirements		9				18				11			12			5		6	0		3		1	1	1
Ct. barriers	9	3	1	4	4	0	1	1	0	0	0	0	5	0	2	1	9	1	3	0	1	1	0	3	5
Aver. import.	3.0	2.7	2.0	3.0	3.5		4.0	3.5					3.0		2.5	3.0	2.4	2.0	2.7		3.0	2.0		NA	
Sum barriers		12				9				2			5			3		10	3		1		1	3	5
Ct. resources	8	0	1	0	7	4	12	2	3	2	0	3	18	0	4	0	3	2	2	2	2	5	1	0	3
Aver. import.	3.4		3.0		2.9	3.0	3.3	3.0	4.0	3.0		3.3	3.5		4.0		3.0	3.0	4.0	3.0	3.0	3.2	3.0		
Sum resources		8				12				19			21			4		5	2		4		6	0	3

Table of footnotes.

No	Text for footnote
1	"Stakeholder analysis aims to evaluate and understand stakeholders from the perspective of an organization, or to determine their relevance to a project or policy. In carrying out the analysis, questions are asked about the position, interest, influence, interrelations, networks and other characteristics of stakeholders, with reference to their past, present positions and future potential," (Brugha and Varvasovszky, 2000) "We define stakeholder analysis as a process that: i) defines aspects of a social and natural phenomenon affected by a decision or action; ii) identifies individuals, groups and organizations who are affected by or can affect those parts of the phenomenon (this may include nonhuman and non-living entities and future generations); and iii) prioritizes these individuals and groups for involvement in the decision-making process," (Reed et al., 2009)
2	The replacement values of the public system (i.e. without private house connections) are typically US\$ 2,600 cap ⁻¹ for large countries (I, UK, F, D, USA), and US\$ 4,800 cap ⁻¹ for small countries (DK, CH, A; Maurer et al., 2005). The annual investment need in OECD countries in the aging water sector is estimated at 0.75% of GDP (Cashman and Ashley, 2008), which translates into US\$ 300,000 million annually (OECD, 2012).
3	Few countries (e.g. UK, France, Czech Republic, and Spain for the sewerage services) are served to around 50% by private companies.
4	In summer, the oxygen content of the deeper water layers approaches 0 mg O ₂ /l, and fish cannot live there. If solar radiation increases the temperature of surface water layers, there is consequently a danger of fish death (AWEL, 2003).
5	The water sector in England and Wales has undergone a very different development than most other European countries. Following privatization

No	Text for footnote
	(see e.g. Guy, 1997), water companies faced the difficulty of ensuring sustained profits in the mature, regulated, low-growth water sector (Bakker, 2003). Some utilities then pursued a strategy of horizontal integration by creating multi-utilities (electricity, gas, water, and telecommunications), or pursuing joint ventures. As Bakker (2003, 2005) shows, the British privatization model combined with regulatory constraints posed serious threats to the economic viability of the private utilities. This recently led to a period of re-structuring, including vertical de-integration: instead of providing the entire cycle of water services to customers (from water extraction via delivery to treatment and discharge of wastewater), some utilities are separating asset ownership from operation and maintenance, while others propose returning water supply infrastructures to public control, e.g. through corporations (as is a common model in Switzerland).
6	The result of a strategic planning exercise for the city of Berne, which had previously already pursued a growth strategy, was “to expand its strategy range along the dimension of ‘new business fields’ by considering the operation of communal and non-communal satellite plants. Kloten-Opfikon decided to pursue a geographical growth strategy. The strategy aims at integrating several neighboring wastewater treatment organizations and the corresponding sewer networks into one organization that provides a wastewater treatment service for a larger region. By contrast, Dübendorf decided to expand along the dimension of vertical integration” (Dominguez et al., 2009).
7	For the Swiss region of Klettgau, near the German border, the stakeholders of a strategic planning exercise preferred the option of “removing the regional WWTP and connecting the sewers to a larger plant in Germany”, i.e. to “extend the system boundaries beyond the national borders to Germany” (Truffer et al., 2010).
8	Today, a Swiss household pays around CHF 75–250 annually in wastewater taxes. In a representative population survey, respondents were willing to pay on average a local tax increase of CHF 240 person-1 year-1; Veronesi et al., 2013.

Supplementary Data to paper:

Stakeholder analysis combined with social network analysis provides fine-grained insights into water infrastructure planning processes

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1. Case study

The case study consists of the four communities Egg, Gossau, Grüningen, and Mönchaltorf, with different entities owning and being responsible for water supply and wastewater disposal (Tab. SD-A). Part of the responsibility is in the hands of the private owners, the communities are responsible for some parts of the system, and cooperatives between communities or at the regional level are again responsible for certain parts of the system.

Table SD-A. Case study. Ownership and responsibility for different parts of the water supply and wastewater disposal system in the four case study communities near Zürich.

	Egg	Gossau	Grüningen	Mönchaltorf
Water supply				
House connection lines	Community Egg	House owners	Cooperative society	Community Mönchaltorf
Distribution of water	Community Egg	Cooperatives (Grüt-Gossau, Bertschikon)	Cooperative (OGH ^a)	Community Mönchaltorf
Raw water and water treatment	Community Egg; delivery via two cooperatives (GVWZO ^b , Uster/Maur)	Community Gossau; delivery via cooperative (GVWZO ^b)	Community Grüningen; delivery via cooperative (GVWZO ^b)	Nearly exclusively outside community with the exception of emergency water; delivery via two cooperatives (GVWZO ^b , Uster/Maur)
Wastewater disposal				
House connection lines	House owners	House owners	House owners	House owners
Sewers	Community Egg	Community Gossau	Community Grüningen	Community Mönchaltorf
Wastewater treatment plant (WWTP)	Joint wastewater management authority, WWTP Egg-Oetwil a. See (= WWTP Esslingen)	Joint wastewater management authority, WWTP Gossau-Grüningen	Joint wastewater management authority, WWTP Gossau-Grüningen	Community Mönchaltorf, WWTP Mönchaltorf
Wastewater outlet to river	Mülibach	Gossauerbach, then Mönchaltorfer Aa	Gossauerbach, then Mönchaltorfer Aa	Mönchaltorfer Aa

^a OGH: Wasserversorgungsgenossenschaft Ober-Ottikon, Grüningen, Hombrechtikon (water supply cooperative of the communities Ober-Ottikon, Grüningen, Hombrechtikon)

^b GWVZO: Gruppenwasserversorgung Zürcher Oberland (group water supplier of a region near Zürich that includes the smaller case study area)

2. Interview partners and categorization

See Table SD-B, next page

Lienert, Schnetzer, Ingold (2013) Stakeholder analysis combined with social network analysis provides fine-grained insights into water infrastructure planning processes. Journal of Environmental Management 125: 134-148.

Table SD-B. Stakeholders. Overview of the 66 stakeholders that were mentioned to play a role in water infrastructure planning (column “Original no.”), merged to 41 main actors (columns 1 & 2, “No.” & “Stakeholder”). “Stakeholder abbreviation” as in Figs. and Tabs. We conducted 27 interviews (“Interview partner”, “Interview no.”). We also show classifications used for further analysis. WS: water supply; WW: wastewater; WWTP: wastewater treatment plant; GEP: “Generelle Entwässerungs Planung”; urban drainage planning in Switzerland.

No.	Stakeholder	Stakeholder abbreviation	Original no.	Details; merged stakeholders	Interview partner/ date of interview	Interview no.	Water sector	Decision level	Sector	Sector detail	Main interest	Water interest	Private / communal	Community
1	WS local engineer	WS local engineer	9	Water supply engineer	C. Meier, Frei & Krauer AG, 20.12.10 M. Rauber, Ernst Basler & Partner, 05.01.11	11, 12	WS	Local	Practice	Industry & engineers	Economy	Water use	Private	Gossau, Grüningen
2	WW local engineer (urban drainage, WWTP)	WW local engineer	1, 14	Urban drainage engineer, wastewater treatment plant engineer	H. Meier, Wesendanger AG, 13.05.11	20	WW	Local	Practice	Industry & engineers	Economy	Water use	Private	Grüningen
3	WS local planning consultant (community engineer, hydrogeologist)	WS local planner	11, 49	Community engineer, hydrogeologist			WS	Local	Practice	Industry & engineers	Economy	Water use	Private	
4	WW local planning consultant (urban drainage, WWTP planning engineer)	WW local planner	28, 30	GEP planning engineer, WWTP planning engineer			WW	Local	Practice	Industry & engineers	Economy	Water use	Private	
5	WS industry (water equipment manufacturers, industry consumers)	WS industry	52, 64	Water supply equipment manufacturers, industrial water consumers			WS	Local	Practice	Industry & engineers	Economy	Water use	Private	
6	WW sewer maintenance companies	WW sewer companies	58	Sewer maintenance companies	D. Nater, Hänni AG, 16.05.11	22	WW	Local	Practice	Industry & engineers	Economy	Water use	Private	Gossau, Egg
7	Other utilities (electricity, telecommunication, construction companies)	Other utilities	41, 42, 43	Electricity utility, telecommunication company, construction company			WS & WW	Local	Practice	Industry & engineers	Economy	Other	Private	
8	WS operating staff & emergency response team	WS operating staff	31, 34	Operating staff water supply, emergency response team water supply	R. Grob, Mönchaltorf, 20.01.11 E. Meili, Egg, 04.04.11	13, 18	WS	Local	Practice	Operators	Technical	Water use	Communal	Mönchaltorf, Egg
9	WW operating staff (urban drainage, WWTP)	WW operating staff	15, 23	Operating staff urban drainage, operating staff wastewater treatment	R. Grob, Mönchaltorf, 20.01.11	13	WW	Local	Practice	Operators	Technical	Water use	Communal	Mönchaltorf
10	WS regional water supplier (GWZO management, operation, associates)	WS water supplier GWZO	18, 26, 27	Group water supply Zürich Oberland (GWZO), management, operating staff, associates	H. Brändle, GWZO management, 16.12.10 M. Balaman, GWZO personnel, 16.12.10	10, 10	WS	Local	Practice	Operators	Technical	Water use	Communal	All four communities
11	WS regional water supplier (regional cooperative directorate, associates)	WS water supplier cooperative	8, 13, 21	Board water supply cooperative, members water cooperative, board water supply on wastewater planning	W. Gubler, Grüningen, board WS cooper., 14.09.10 R. Rhunke, Bertschikon, board WS cooper., 01.11.10 H. Stauber, Grüt-Gossau, board WS cooper., 04.11.10	2, 3, 4	WS	Local	Practice	Operators	Technical	Water use	Communal	Grüningen, Gossau
12	WW joint regional WWTP association	WW joint WWTP assoc.	10	Joint wastewater treatment plant authority	M. Hugger, Grüningen, joint WWTP authority, 16.11.10 M. Huber, Gossau, joint WWTP authority, 15.12.10	7, 9	WW	Local	Practice	Operators	Technical	Water use	Communal	Grüningen, Gossau
13	WS municipal administration for water supply	WS munic. admin.	2	Local construction administration water supply	H. Hungerbühler, Mönchaltorf, 20.01.11	14	WS	Local	Administration & politics	Admin: WS	Technical	Water use	Communal	Mönchaltorf
14	WS municipal managing board for underground engineering, water supply	WS munic. underground engin.	4	Local politician in charge of water supply			WS	Local	Administration & politics	Politics	Civil society	Water use	Communal	
15	WW municipal administration for wastewater	WW munic. admin.	3	Municipal administration for wastewater	M. Lutzmann, Gossau, 09.11.10 H. Hungerbühler, Mönchaltorf, 20.01.11	5, 14	WW	Local	Administration & politics	Admin: WW	Technical	Water use	Communal	Gossau, Mönchaltorf
16	WW municipal managing board for underground engineering, wastewater	WW munic. underground engin.	5	Local politician in charge of wastewater	M. Hugger, Grüningen, 16.11.10 M. Huber, Gossau, 15.12.10	7, 9	WW	Local	Administration & politics	Politics	Civil society	Water use	Communal	Gossau, Grüningen
17	WS municipal fire department	WS munic. fire	48	Local fire department			WS	Local	Administration & politics	Admin: others	Civil society	Water use	Communal	
18	WS municipal managing board for health	WS munic. health	29	Local politician in charge of health			WS	Local	Administration & politics	Politics	Civil society	Water use	Communal	
19	Municipal managing boards for aboveground engineering, utilities, finance	Munic. eng n., utilities, finance	16, 53, 63	Local politician in charge of construction, works commission, local politician in charge of finances			WS & WW	Local	Administration & politics	Politics	Civil society	Water use	Communal	
20	Municipal politicians (municipal council, municipal assembly)	Munic. politicians	57, 62	Local council, municipal assembly			WS & WW	Local	Administration & politics	Politics	Civil society	Other	Communal	
21	Citizens, tourists	Citizens, tourists	20, 40	Citizens, tourists, cooperative members of water supply			WS & WW	Local	Public	Public	Civil society	Water use	Private	
22	Land owners, real estate companies	Land owners	12, 19	Land owner, real estate companies			WS & WW	Local	Public	Public	Economy	Water use	Private	

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Table SD-B. Continued.

No.	Stakeholder	Stakeholder abbreviation	Original no.	Details; merged stakeholders	Interview partner/ date of interview	Interview no.	Water sector	Decisional level	Sector	Sector detail	Main interest	Water interest	Private / communal	Community
23	WS cant. agency for waste, water, energy and air (AWEL, water supply)	WS cant. agency AWEL	6	Cantonal agency for waste, water, energy and air (AWEL, water supply), section ground water	P. Ruckstuhl, AWEL, technical water supply plants ct. ZH, 28.01.11	17	WS	Cantonal	Administration & politics	Admin: WS	Civil society	Water use	Communal	All four communities
24	WW cant. agency for waste, water, energy and air (AWEL, wastewater)	WW cant. agency AWEL	7, 25, 36, 33, 37	Cantonal agency for waste, water, energy and air (AWEL, wastewater), sections urban drainage/ planning & support/ WWTP/ hydraulic construction/ in-plant environmental protection	S. Schmid, AWEL, planning & support, 10.12.10 P. Wolfensberger, AWEL, inspector water protection, 11.11.10	8, 6	WW	Cantonal	Administration & politics	Admin: WW	Environment	Water protection	Communal	All four communities
25	WS cant. agency for drinking water quality (cant. laboratory, assoc. cant. chemists VKCS)	WS cant. lab., chemists	17, 61	Cantonal laboratory, association of cantonal chemists (VKCS)			WS	Cantonal	Administration & politics	Admin: others	Civil society	Water protection	Communal	
26	WS cant. office for landscape & nature ALN (dept. agriculture) & office for melioration	WS cant. office agriculture ALN	39, 47	Cantonal office for landscape & nature ALN (department of agriculture) & office for melioration			WS	Cantonal	Administration & politics	Admin: others	Civil society	Water use	Communal	
27	WS cant. insurance on buildings GVZ (fire)	WS cant. insurance fire GVZ	32	Cantonal insurance on buildings GVZ (fire authority)	K. Steiner, GVZ, 15.06.11	26	WS	Cantonal	Administration & politics	Admin: others	Civil society	Water use	Communal	All four communities
28	WW cant. office for landscape & nature ALN (dept. hunting & fisheries)	WW cant. office fisheries ALN	38	Cantonal office for landscape & nature ALN (department hunting & fisheries)	A. Hertg, ALN, 25.01.11	16	WW	Cantonal	Administration & politics	Admin: others	Environment	Water protection	Communal	All four communities
29	Cant. office for underground engineering	Cant. underground eng.n.	35	Cantonal office for underground engineering, canton Zürich			WS & WW	Cantonal	Administration & politics	Admin: others	Civil society	Water use	Communal	
30	Cant. office for spatial development ARE	Cant. office spat. devel. ARE	22	Cant. office for spatial development ARE			WS & WW	Cantonal	Administration & politics	Admin: others	Civil society	Other	Communal	
31	Cantonal council (politicians, "Regierungsrat")	Cant. politicians	24	Cantonal council (politicians, "Regierungsrat")			WS & WW	Cantonal	Administration & politics	Politics	Civil society	Other	Communal	
32	WS Swiss association of gas and water professionals SVGW	WS nat. assoc. SVGW	44	Swiss association of gas and water professionals SVGW	U. Kamm, SVGW, 19.05.11	23	WS	National	Practice	Water associations	Civil society	Water use	Communal	Not on communal level
33	WW Swiss association of wastewater & water protection professionals VSA, communal infrastructure association	WW nat. assoc. VSA	54, 66	Swiss association of wastewater & water protection professionals VSA, communal infrastructure association (interview not analyzed)	M. Würsten, VSA, 26.05.11 A. Bukowiecki, KI, 17.06.2011 (interview not used)	24, 27	WW	National	Practice	Water associations	Civil society	Water use	Communal	Not on communal level
34	Swiss network of actors in the water sector "Water-Agenda 21"	Water-Agenda 21	65	Water Agenda 21	S. Voitenweider, WA21, 24.01.11	15	WS & WW	National	Practice	Water associations	Civil society	Water protection	Communal	Not on communal level
35	WS Federal office for the environment FOEN, division water, groundwater protection section	WS nat. groundwater FOEN	45	Federal office for the environment FOEN, division water, groundwater protection section	B. Meylan, FOEN GW, 06.06.11	25	WS	National	Administration & politics	Admin: WS	Environment	Water protection	Communal	Not on communal level
36	WW Federal office for the environment FOEN, division water, quality of surface waters section	WW nat. surface water FOEN	46	Federal office for the environment FOEN, division water, quality of surface waters section	M. Schärer, FOEN Surf, 12.05.11	19	WW	National	Administration & politics	Admin: WW	Environment	Water protection	Communal	Not on communal level
37	WS Federal office of public health FOPH	WS nat. health FOPH	59	Federal office of public health FOPH			WS	National	Administration & politics	Admin: others	Civil society	Water protection	Communal	Not on communal level
38	WS Federal office for agriculture FOAG	WS nat. agriculture FOAG	60	Federal office for agriculture FOAG			WS	National	Administration & politics	Admin: others	Civil society	Water use	Communal	Not on communal level
39	Non-Governmental Organizations NGOs	NGOs	55	Non-Governmental Organizations NGOs			WS & WW	National	Public	Public	Environment	Water protection	Communal	Not on communal level
40	WS Swiss federal institute of aquatic science and technology Eawag (water supply)	WS Eawag	50	Swiss federal institute of aquatic science and technology Eawag (water supply), department water resources & drinking water	R. Kipfer, RoKi, Eawag W&T, 16.05.11	21	WS	National	Science	Science	Environment	Water protection	Communal	Not on communal level
41	WW Swiss federal institute of aquatic science and technology Eawag (wastewater)	WW Eawag	51	Swiss federal institute of aquatic science and technology Eawag (wastewater), department urban water management	J. Reckermann, Eawag SWW, 09.09.10	1	WW	National	Science	Science	Environment	Water protection	Communal	Not on communal level

3. Influence on and being affected by water planning

Figure SD-A. Perceived mean influence on and being affected by water infrastructure planning. Scale from 0 (“actor has no influence/ is not at all affected”) to 10 (“actor decides/ is very strongly affected by planning results”), grouped according to the sector (A), assigned water interest (B), and private or communal. The size of the symbols is proportional to the times an actor was mentioned across different interviews. The actors are numbered (see Tab. SD-B; further explanations see main text).

4. Network analysis

4.1. Centrality measures and core/ periphery analysis

Table SD-C. Results of the network analysis. We show the degree and betweenness centrality in the network (see Methods and Results main text) of each stakeholder (Tab. SD-B). Water sector: 1= water supply, 2= wastewater, 3= both; Decision level: 1= local, 2= cantonal, 3= national; Sector: 1= practice, 2= administration & politics, 3= public, 4= science; Core/ periphery: 1= core, 2= periphery.

No.	Stakeholder abbreviation	Degree	Between- ness	Water sector	Decision- al level	Sector	Core/ periphery
19	Munic. engin., utilities, finance	0.325	0.523	3	1	2	1
13	WS munic. admin.	0.300	0.293	1	1	2	1
24	WW cant. agency AWEL	0.300	0.435	2	2	2	1
1	WS local engineer	0.275	0.284	1	1	1	1
2	WW local engineer	0.275	0.430	2	1	1	1
11	WS water supplier cooperative	0.275	0.404	1	1	1	1
15	WW munic. admin.	0.250	0.279	2	1	2	1
14	WS munic. underground engin.	0.225	0.169	1	1	2	1
16	WW munic. underground engin.	0.225	0.191	2	1	2	1
23	WS cant. agency AWEL	0.200	0.100	1	2	2	1
3	WS local planner	0.175	0.237	1	1	1	1
4	WW local planner	0.175	0.203	2	1	1	1
8	WS operating staff	0.175	0.085	1	1	1	1
10	WS water supplier GWVZO	0.175	0.035	1	1	1	1
12	WW joint WWTP assoc.	0.175	0.051	2	1	1	1
25	WS cant. lab., chemists	0.175	0.281	1	2	2	1
9	WW operating staff	0.125	0.171	2	1	1	0
27	WS cant. insurance fire GVZ	0.125	0.174	1	2	2	0
5	WS industry	0.100	0.183	1	1	1	0
17	WS munic. fire	0.100	0.162	1	1	2	0
21	Citizens, tourists	0.100	0.136	3	1	3	0
33	WW nat. assoc. VSA	0.100	0.111	2	3	1	0
35	WS nat. groundwater FOEN	0.100	0.091	1	3	2	0
26	WS cant. office agriculture ALN	0.075	0.053	1	2	2	0
30	Cant. office spat. devel. ARE	0.075	0.110	3	2	2	0
6	WW sewer companies	0.050	0.069	2	1	1	0
28	WW cant. office fisheries ALN	0.050	0.042	2	2	2	0
29	Cant. underground engin.	0.050	0.070	3	2	2	0
32	WS nat. assoc. SVGW	0.050	0.103	1	3	1	0
36	WW nat. surface water FOEN	0.050	0.050	2	3	2	0
7	Other utilities	0.025	0.025	3	1	1	0
18	WS munic. health	0.025	0.050	1	1	2	0
22	Land owners	0.025	0.035	3	1	3	0
39	NGOs	0.025	0.017	3	3	3	0
20	Munic. politicians	0	-1.732E-19	3	1	2	0
31	Cant. politicians	0	-1.180E-09	3	2	2	0
34	Water-Agenda 21	0	-6.685E-10	3	3	1	0
37	WS nat. health FOPH	0	6.684E-08	1	3	2	0
38	WS nat. agriculture FOAG	0	6.609E-18	1	3	2	0
40	WS Eawag	0	0	1	3	4	0
41	WW Eawag	0	0	2	3	4	0

4.2. Additional network analyses

The cooperation network analyzed by the sector each actor belongs to confirms that the central and well-connected actors come from practice (red nodes in Fig. SD-B) and administration & politics (blue nodes). Especially the previously mentioned two local and cantonal bodies from administration & politics play a central role (Munic. engin., utilities, finance; SH 19; and WW cant. agency AWEL; SH 24; stakeholder details see Tab. SD-B), indicated with the high betweenness centrality (large size of blue nodes; Tab. SD-C). The representatives of the public are peripheral and have few ties to others, i.e. citizens and tourists (SH 21), and even more peripheral are the NGOs (SH 39; black nodes). The two science representatives from our water research institute Eawag (SH 40, 41) do not even participate in the cooperation network (listed top left, grey nodes). Moreover, the network analysis indicates that there is some collaboration across sectors (i.e. horizontal collaboration), and especially between some local practice actors and cantonal agencies (i.e. ties between red and blue nodes; compare with Fig. 3, main text). However, there are few (or no) ties linking the science and the public representatives to water infrastructure planning, and there are also very few direct ties between different authorities from administration & politics (i.e. between different blue nodes). This confirms horizontal fragmentation between and within sectors.

Figure SD-B. Cooperation network by sector. Red nodes indicate actors from practice, blue nodes from administration & politics, black nodes indicate representatives from the public and grey nodes from science. The size of the node indicates an actor's betweenness centrality (see text and Tab. SD-C). More details concerning the actors see Tab. SD-B.

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The cooperation network analyzed by the perceived influence an actor has on water infrastructure planning confirms that those actors that were rated by the interview partners to have a high or very high influence are also central in the network (black nodes, Fig. SD-C; rated 5–10 on a scale of 0–10). Interestingly, two actors with a high perceived influence do not at all participate in the network (black nodes, listed top-left): the municipal politicians (average influence 7.7; SH 20; Tab. SD-B) and the cantonal politicians (average influence 9; SH 31). This is an indication that some interview partners did perceive already in part I of the stakeholder analysis that politicians have strong decision making power and can thus strongly influence water infrastructure planning; however, they did not see how these politicians are actually tied into the local infrastructure planning process. Additionally, it must be noted that politicians were mentioned by only three/ one interview partners, respectively, which helps to explain their lack of embeddedness in the network. Some actors with medium influence (on average rated 3–5; blue nodes) are more central in the network, but quite a number of them are at the periphery, or even outside the network (listed top-left). Following the intuitive expectation, those stakeholders with low or even no influence on water infrastructure planning are very peripheral to the network, with only loose ties to others (red nodes). An exception here is the local planner for wastewater (WW local planner; SH 4), who was rated to have a very low influence (2.8) by the three interview partners that mentioned him, but does seem to have a number of ties to other actors; which is also confirmed in a relatively high betweenness centrality of 0.203 (Tab. SD-C).

Figure SD-C. Cooperation network by perceived influence. Black nodes indicate that actors were perceived to have a strong or even very strong influence on water infrastructure planning (rating 5–10; see Methods). Blue nodes indicate actors that were perceived to have some influence (rating 3–5), and red nodes are actors that have little or no influence (rating 0–3). The size of the node indicates an actor's betweenness centrality (see text and Tab. SD-C). More details concerning the actors see Tab. SD-B.

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Figure SD-D. Cooperation network by perceived affectedness. Red nodes indicate that actors were perceived to be affected or even strongly to very strongly affected by water infrastructure planning (rating 5–10; see Methods). Blue nodes indicate actors that were perceived to be somewhat affected (rating 3–5), and black nodes little or not at all affected (rating 0–3). The size of the node indicates an actor's degree centrality (see text and Tab. SD-C). More details concerning the actors see Tab. SD-B.

5. Perceived main interests

We assigned the perceived interests of each stakeholder that included any similar meaning to one of eight main categories. Because the same stakeholders were assessed by different interview partners, usually one stakeholder had several “main” interests:

- **Economic:** low costs, cost-efficiency, making a profit, customer satisfaction, receiving a subsequent contract, keeping a mandate, keeping wastewater fees low, compensation for building activities on one's land, etc.
- **Planning:** preparation/ implementation of network planning, good/ strategic planning, supplying areas for agriculture/ wastewater disposal/ etc., land use planning, etc.
- **Technical:** state of the art technology, sound technical solution, functioning system, good rehabilitation, sufficient maintenance, good state of the infrastructure/ WWTP/ sewer/ etc., high standard, sustainable technical solutions, sufficient capacity, simple technical solution, functional assets, use of high quality materials, etc.
- **Management & operation:** good project management, simple operations, user friendliness, no complaints, security of operations, easy handling, professionalism, etc.
- **Legal:** legal compliance, comply with service contract/ standards/ etc., implementation of regulations, execute fisheries law, harmonization of guidelines, etc.
- **Environmental:** protection of water/ groundwater/ rivers/ etc., good water quality, avoid depletion of ground water, secure environmental and flood protection, protect resources, minimal impact through wastewater, no aesthetic disturbance by wastewater, etc.
- **Societal:** social acceptance/ interests, participation, cooperation, acceptance of planning, information, fulfill expectations of citizens, democratic planning, develop new residential areas, construction activities in the community, good reputation, prestige, good relationship to the local politics, etc.
- **Water infrastructure services:** supply water to the districts/ to the people/ to agriculture/ for firefighting/ etc., optimal/ safe/ reliable water supply/ wastewater disposal/ drainage of wastewater from roads/ etc., reliable services, no interruptions of water supply, comfortable drainage, high quality of drinking water, hygiene, no floodings, etc.

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Table SD-D. Perceived main interests of important actors for water infrastructure planning elicited in the 26 stakeholder interviews. We show the average and total number of times interest was mentioned over all stakeholders, and the average number of times an interest was assigned to stakeholders that were classified according to different groups (see Methods).

Over all stakeholders	Economic	Planning	Technical	Managem. & operation	Legal	Environ-mental	Societal	Water infrastructure services
Average	2.78	0.54	1.66	0.68	1.07	0.71	0.73	1.63
Total count	114	22	68	28	44	29	30	67
Water sector								
Water supply	2.37	0.53	1.42	0.89	1.26	0.47	0.58	1.68
Wastewater	3.58	0.83	2.50	0.67	1.67	0.92	0.58	1.17
Both water sectors	2.60	0.20	1.10	0.30	0	0.90	1.20	2.10
Decisional level								
Local	5.05	0.73	2.91	1.14	0.55	0.41	1.32	2.27
Cantonal	0.22	0.67	0.22	0.22	2.56	1.78	0.11	1.44
National	0.10	0	0.20	0.10	0.90	0.40	0	0.40
Sector								
Practice	3.80	0.73	2.73	0.80	0.53	0.20	0.47	1.00
Administration & politics	2.00	0.52	1.05	0.76	1.71	1.00	0.95	1.71
Public	4.67	0	1.33	0	0	1.67	1.00	5.33
Science	0.50	0	0.50	0	0	0	0	0
Sector details								
Engineers & industry	6.29	1.29	3.43	0.14	0.14	0.14	0.71	0.29
Operators	2.60	0.40	3.20	2.00	0.60	0.40	0.40	2.20
Administration water supply	2.00	1.67	1.33	1.67	4.00	2.33	0.33	1.33
Administration wastewater	3.00	0.67	1.33	1.00	4.33	2.67	1.00	1.67
Administration others	0	0.33	0.11	0.22	0.89	0.44	0	1.22
Politics	4.50	0.17	2.17	1.00	0.50	0.33	2.67	2.67
Public	4.67	0	1.33	0	0	1.67	1.00	5.33
Water associations	0	0	0.33	0.33	1.33	0	0	0.67
Science	0.50	0	0.50	0	0	0	0	0
Private / communal								
Private	6.44	1.00	3.11	0.11	0.11	0.56	0.89	2.00
Communal	1.75	0.41	1.25	0.84	1.34	0.75	0.69	1.53
Main interest								
Economic	5.88	1.13	3.00	0.13	0.13	0.13	0.63	0.63
Technical	3.71	0.86	3.29	2.43	1.14	0.43	0.71	2.14
Civil societal	2.05	0.32	1.05	0.53	1.00	0.63	1.05	2.37
Environmental	0.29	0.14	0.14	0.00	2.29	1.86	0	0.29
Water interest								
Water use	3.89	0.70	2.33	1.00	0.96	0.52	0.89	2.22
Water protection	0.20	0.10	0.10	0	1.80	1.30	0	0.60
Other	1.75	0.50	1.00	0.25	0	0.50	1.50	0.25

6. Requirements, barriers, resources

6.1. Categorizing the data

To group the data, we used similar classes as for the perceived interests above. We assigned statements about additional requirements to current planning to make it an ideal process, barriers that hinder, and resources that support good planning to one of nine groups (Tab. SD-E):

1. **Economic:** 1.1. More money (lack of finances, increase water price, get subventions, ...); 1.2. More personnel (lack of personnel, not enough capacity, ...)
2. **Planning:** 2.1 Efficiency (develop planning process, delay in implementation, ...); 2.2. Catchment level (integrative planning on catchment level, regional planning, regionalization, ...); 2.3. Horizontal collaboration across sectors (better collaboration between actors on the same (horizontal) level, fragmentation of planning, ...); 2.4. Vertical collaboration from local to cantonal (cooperation community with canton, controlling and support of community through canton, ...).
3. **Technical:** 3.1. Data (good data set, time consuming data administration, existing data, ...); 3.2. Tools (good planning tools, imperfect tools, internet, ...); 3.3. Infrastructure (continuous renovation, good existing infrastructure, ...); 3.4. Equipment (good technical equipment, ...).
4. **Management & operation:** 4.1. Harmonization (... of data sets, ... of systems); 4.2. Commercial relationships (long-term collaboration with engineer, ...); 4.3. Professionalization (diligent operational management, performance standards, bureaucracy, lack of leadership personnel, professional financial management, sufficient engineering capacity, ...).
5. **Legal:** 5.1. Compliance (legal compliance); 5.2. Regulations (additional guidelines, public procurement law, standards, ...); 5.3. More competence (more competences for ..., lack of competences of ...).
6. **Political:** 6.1. System (honorary system, current structure of system, lack of political continuity, favoritism, ...); 6.2. Support (political support for planning, local authorities with positive attitude, lack of technical know-how of decision makers (politicians), ...).
7. **Environmental:** Insufficient prioritization of water protection, missing sustainability concept, water (lake Zürich).
8. **Societal:** 8.1. Participation (active involvement of communities, local embeddedness, voice of water cooperative, stakeholder involvement, ...); 8.2. Awareness (lack of awareness about infrastructure in population, information about infrastructure costs, ...).
9. **Education & research:** 9.1. Practice (terms of reference and continuous education, best practice examples, ...); 9.2. Science (Eawag, international research institute).
10. **OK:** Existing water infrastructure planning is good as it is today, nothing needs to be improved/ no barriers/ no suggestions concerning existing resources that support planning.
11. **No comment:** Interview partner cannot say anything about this topic.

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Table SD-E. Classification of statements concerning additional requirements of current infrastructure planning to make it an ideal planning process, barriers that hinder, and resources that support good planning. We show typical examples of the original wording given in the 27 stakeholder interviews and how these were classified according to nine main topics and 23 sub-topics. GEP: Generelle Entwässerungsplanung (a certain type of urban drainage planning); GWP: Generelle Wasserplanung (a certain type of water supply planning; GWVZO: Gruppenwasserversorgung Zürcher Oberland (group water supplier of a region near Zürich); Leitungskataster: register/ database of the pipes and network.

Original wording ideal planning	Original wording barriers	Original wording resources
1. Economic		
1.1. Economic: more money (Econ money)	1.1. Economic: more money (Econ money)	1.1. Economic: more money (Econ money)
Financing / ... view planning as important investment	Lack of financing	Financial resources / ... fees, water bills, taxes / ... planning system
Increase of water prices	Price war in construction	Financial resources by fire authorities for hydrants
Financing: subventions / financial support by canton	Strong prioritization of cost savings in communities	Subventions
1.2. Economic: more personnel (Econ personnel)	1.2. Economic: more personnel (Econ personnel)	1.2. Economic: more personnel (Econ personnel)
More qualified personnel (for the canton, to be present in communities)	Not enough capacity / lack of personnel	
More personnel for planning and operation		
2. Planning		
2.1. Planning: efficiency (Plann effc)	2.1. Planning: efficiency (Plann effc)	2.1. Planning: efficiency (Plann effc)
Efficiency enhancement of planning / ... with fewer steps	Delay in implementation of planning (GWP)	Local specification of planning
Rolling planning process		
Experienced planners		
Development of infrastructure management practice		
2.2. Planning: catchment level (Plann catchm)	2.2. Planning: catchment level (Plann catchm)	2.2. Planning: catchment level (Plann catchm)
Integrative planning on catchment/ cantonal level	Insufficient prioritization of integrative planning	
More competencies of cantons to carry out regional planning	Conflicts of interests between community and regional planning	
Regionalization of planning	Small-scale thinking in community / ... in canton	
2.3. Planning: horizontal collaborat. across sectors (Plann horiz)	2.3. Planning: horizontal collaborat. across sectors (Plann horiz)	2.3. Planning: horizontal collaborat. across sectors (Plann horiz)
Use of synergies	Different culture in sectors	Professional exchange / ... betw. sectors / ... with GWVZO
Constant synchronization of planning agencies	Scarce information	Professional exchange with similar engineering companies
Better collaborat. betw. actors (AWEL, statist. office, cantonal laborator.)	Insufficient coordination	Services from other companies
Involve cantonal office for landscape & nature (ALN) in planning process	Fragmentation of planning	Support fr. companies for emergency response (sanitary firms, digging)
Participation of fire service in planning process	Insufficient integrative planning (GEP with GWP)	Synergies in implementation
2.4. Planning: vertical collaborat.; local to cantonal (Plann vert)	2.4. Planning: vertical collaborat.; local to cantonal (Plann vert)	2.4. Planning: vertical collaborat.; local to cantonal (Plann vert)
Cooperation engineer, community, canton / ... for GEP-planning		Controlling & support through canton / ... (fire authorities) for communities
3. Technical		
3.1. Technical: data (Techn data)	3.1. Technical: data (Techn data)	3.1. Technical: data (Techn data)
Very good data set	Time consuming data administration	Existing data / ... plans about infrastructure / ... GEP / ... GIS
Good threshold values/ indicators		Existing data (concerning the location and maintenance of each hydrant)
		Existing data and data management ("Leitungskataster")
		Good data set / ... concerning fish-relevant factors
		Data compatibility
3.2. Technical: tools (Techn tools)	3.2. Technical: tools (Techn tools)	3.2. Technical: tools (Techn tools)
Engineering tools	Imperfect tools	Existing engineering planning tools of community
Good planning tools / ... all maintenance in GIS / ... maintenance costs		Internet
IT support for planning fundamentals		
3.3. Technical: infrastructure (Techn infrastr)	3.3. Technical: infrastructure (Techn infrastr)	3.3. Technical: infrastructure (Techn infrastr)
Continuous technical renovation and modernization		Good interconnectedness of existing infrastructure
		Good existing technical infrastructure
3.4. Technical: equipment (Techn equipm)	3.4. Technical: equipment (Techn equipm)	3.4. Technical: equipment (Techn equipm)
		Good technical equipment
4. Management & operation		
4.1. Management & operation: harmonization (Manag harmoniz)	4.1. Management & operation: harmonization (Manag harmoniz)	4.1. Management & operation: harmonization (Manag harmoniz)
Harmonization of data sets (renewal of data also by planners & community) / ... of systems		
4.2. Manag. & oper: commercial relationsh. (Manag com relat)	4.2. Manag. & oper: commercial relationsh. (Manag com relat)	4.2. Manag. & oper: commercial relationsh. (Manag com relat)
Long-term relationships (community - engineer) / ... commercial relations		Longstanding collaboration of community with engineer and operator
4.3. Management & operation: professionalization (Manag profess)	4.3. Management & operation: professionalization (Manag profess)	4.3. Management & operation: professionalization (Manag profess)
Professionalization	Lack of professionalism and understanding	Professional financial management
Diligent operational management	Lack of professional structures (especially in cooperatives)	Legal Know-how
Keep to time schedules in planning (GWP)	Bureaucracy	Responsibility for technical know-how / technical know-how
Professional financial management / sustainable financial management	Legal Know-how	Qualified personnel / professional experience
Transparent cost & benefit structures	Lack of personnel (eng neers)	Engineering capacity (creativity of engineers)
Performance standards & controlling	Lack of personnel w th leadership abilities	Sufficient engineering capacity (can be bought)
Monitoring of the planning process		Professional exchange with other water utility operators
More qualified personnel / technical know-how		Organizational form that allows feedback of associates to management

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Table SD-E. Continued.

Original wording ideal planning	Original wording barriers	Original wording resources
5. Legal		
5.1. Legal: compliance (Legal compl)	5.1. Legal: compliance (Legal compl)	5.1. Legal: compliance (Legal compl)
Legal compliance		
5.2. Legal: regulations (Legal regul)	5.2. Legal: regulations (Legal regul)	5.2. Legal: regulations (Legal regul)
Adequate additional guidelines to initiate and support regional planning	Varying engineering quality due to procurement (choice of cheapest offer)	Standards
	Public procurement law (threshold levels; communities choose cheapest)	Existing local and cantonal instruments / ... GEP, Verbands-GEP
		Groundwater protection areas
5.3. Legal: more competence (Legal compet)	5.3. Legal: more competence (Legal compet)	5.3. Legal: more competence (Legal compet)
Concentration of competences at cantonal level	Lacking of competences from canton, communities, engineers	
More financial competences for operator and communal politicians		
6. Political		
6.1. Political: system (Polit syst)	6.1. Political: system (Polit syst)	6.1. Political: system (Polit syst)
Honorary system	Current structure of the communities	Honorary system
Shorter decision-making process	Delay in decision-making caused by system	
Decoupling from the political system	Lack of political continuity / ... elections of head of WWTP every 4 yrs.	
	Coupling of local politics with infrastructure / ... technical questions	
	Favoritism (contacts with local politicians help to receive mandate)	
	Practical policy / party ideology	
6.2. Political: support for planning (Polit supp)	6.2. Political: support for planning (Polit supp)	6.2. Political: support for planning (Polit supp)
Appraisal and development of infrastructure management	Lack of technical know-how of decision-makers (politicians)	Local authorities with positive attitude
Political support for planning		Technical Know-how of community to actively lead project
7. Environmental (Envir)		
	Insufficient prioritization of water protection	Water (lake Zürich)
	Missing sustainability concept	
8. Societal		
8.1. Societal: participation (Soc partic)	8.1. Societal: participation (Soc partic)	8.1. Societal: participation (Soc partic)
Active involvement of communities in planning/ local embeddedness		Stakeholder involvement
Participation of operator and operating staff in planning		Close links between end-user and operator
Voice of the water cooperative		
8.2. Societal: awareness (Soc aware)	8.2. Societal: awareness (Soc aware)	8.2. Societal: awareness (Soc aware)
	Lack of awareness about infrastructure rehabilitation from population	Information about infrastructure costs for population and politics
	Lack of awareness about infrastructure functioning in population	Population understands operator of water supplier (e.g. if interruptions)
9. Education & research		
9.1. Education & research: practice (Educ pract)	9.1. Education & research: practice (Educ pract)	9.1. Education & research: practice (Educ pract)
Terms of reference and continuous education	Missing of specific education	Best practice examples
		Continuous education
		Support / ... technical know-how through water sector associations
9.2. Education & research: science (Educ sci)	9.2. Education & research: science (Educ sci)	9.2. Education & research: science (Educ sci)
		Eawag / ... international research institute
10. OK		
Existing planning is good as it is today, nothing needs to be improved	There are no barriers that hinder the current planning	No suggestions concerning existing resources that support planning
11. No comment		
Stakeholder cannot say anything concerning ideal planning	Stakeholder cannot say anything about barriers that hinder planning	Stakeholder cannot say anything about resources that support planning

6.2. Differences between groups

Table SD-F shows the average number of times additional requirements for ideal planning, compared with today were mentioned, barriers that hinder and resources that support good planning – within different stakeholder groups and main topics. Here, we first summarize some patterns that differentiate between stakeholder groups (details see below and Tab. SD-F).

Nearly all groups of actors mentioned (4.) *management & operational* and (2.) *planning* aspects as important additional requirements of ideal planning, but also as resource, and sometimes barrier. (1.) *Economic* aspects, an important requirement for most groups, were perceived as barriers, especially by the wastewater sector, local and cantonal actors, administration & politics, operators, communal actors and actors with technical and environmental interests. However, they were also viewed as resource, e.g. by both water sectors and the cantonal representatives. (3.) *Technical* aspects were viewed as important requirement especially by the wastewater sector, local and national actors and the private sector, namely engineers & industry. (5.) *Legal* requirements mostly did not help to differentiate between groups, but were perceived as barriers as well as resource by the wastewater sector, by cantonal actors, societal and environmental interest groups, and mainly as barrier by actors assigned to water protection. (6.) *Political* aspects as important additional requirement, but also resource were important for the water supply sector, local stakeholders, practice actors including engineers & industry (i.e. the private sector) and operators. The wastewater sector perceived political topics mainly as barrier, together with all three decision levels

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(local to national), practice, especially engineers, the private sector and actors with economic interests and interests in water use. Interestingly, the actors that we assigned to have mainly environmental interests did not mention (7.) *environmental* barriers markedly more often than the economic or technical group, and the latter was even alone to mention Lake Zürich as environmental resource. (8.) *Societal* topics were hardly mentioned, but might be viewed as resource by national actors, both science interview partners and actors that were assigned to follow interests in water protection. (9.) Finally, *education & research* was viewed as resource by all three decision levels (local, cantonal, national), engineers & industry, i.e. private actors and the water associations.

6.2.1. Water sector

In the following, we summarize the main findings presented in Table SD-F also in words for each stakeholder group separately (in parentheses the average number of times mentioned per topic and stakeholder group).

For the water supply sector, planning aspects were the most often mentioned additional requirements of ideal planning (0.75), followed by management & operational issues (0.5). The same pattern applied to the wastewater sector, but with less emphasis (0.58 and 0.42, respectively). As reminder: planning aspects include efficiency, as well as regionalization and planning at the catchment level, horizontal collaboration (i.e. across sectors acting on the same level) and vertical collaboration (i.e. spanning different decision levels from local to cantonal or national actors). For the wastewater sector, purely technical aspects also seemed an important additional requirement to ideal planning (0.58). Political requirements were mentioned by one third of the interviewed representatives of the water supply sector, but hardly by the wastewater sector (0.08).

Barriers that hinder good planning for the water supply sector were also mostly related to planning aspects (0.58), but these also seem to provide good resources (0.67) according to the water supply sector. The most important resources for both sectors, however, seemed to be related to management & operation (0.75 both sectors) and technical aspects (water supply: 0.75; wastewater: 0.67). Interestingly, the wastewater sector hardly mentioned planning aspects to provide barriers (0.08), but rather perceived important barriers in the political system (0.67), which was not at all noteworthy for the water supply sector (0.08). The wastewater sector also perceived economic barriers (0.58; water supply: 0.33) and mentioned legal aspects too (0.25 water supply: not mentioned). Economic aspects provided resources to some extent for both water sectors (water supply: 0.25, wastewater: 0.42). The few actors that represented both water sectors also viewed resources in education & research (0.67).

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Table SD-F. Additional requirements to current planning to make it an ideal planning process, barriers that hinder, and resources that support good planning per stakeholder group. Summary of statements from 27 stakeholder interviews, classified according to nine main topics (details concerning topics see Tab. SD-E). We show the sums over all stakeholders, and the “average importance”, i.e. how important the interview partners judged the respective requirement/ barrier/ resource on a scale of 1 (requirement/ barrier/ resource is not significant) to 4 (... is essential). Furthermore, for different groups of stakeholders, we show the average number of times a requirement/ barrier/ resource was mentioned within the respective stakeholder group and main topic (stakeholder classifications see Tab. SD-B). Averages >1 result from a stakeholder mentioning rather different aspects of a main topic, which were thus classified into different sub-topic classes and were counted more than once. All OK: “everything is fine as it is” (no additional requirements needed, no barriers); No comment: interview partner was not able to make a statement about this topic; NA: not applicable.

	Economic	Planning	Technical	Managem. & Oper	Legal	Political	Environm ental	Societal	Educ. & Research	All OK	No comment
Over all stakeholders											
Ideal planning	Econ.	Plann.	Techn.	Manag.	Legal	Polit.	Envir.	Soc.	Educ.	OK	NA
Sum	9	18	11	12	5	6	0	3	1	1	1
Average "importance"	2.9	2.8	3.1	3.2	2.4	2.6		3.0	3.0	3.0	
Barriers											
Sum	12	9	2	5	3	10	3	1	1	3	5
Average "importance"	2.9	3.0	3.8	3.0	2.7	2.4	2.7	3.0	2.0	NA	
Resources											
Sum	8	12	19	21	4	5	2	4	6	0	3
Average "importance"	3.4	3.0	3.3	3.5	4.0	3.0	4.0	3.0	3.1		
Water sector											
Ideal planning	Econ.	Plann.	Techn.	Manag.	Legal	Polit.	Envir.	Soc.	Educ.	OK	NA
Water supply	0.33	0.75	0.25	0.50	0.17	0.33		0.08			0.08
Wastewater	0.33	0.58	0.58	0.42	0.08	0.08		0.17		0.08	
Both water sectors	0.33	0.67	0.33	0.33	0.67	0.33			0.33		
Barriers											
Water supply	0.33	0.58	0.08	0.25		0.08				0.08	0.17
Wastewater	0.58	0.08	0.08	0.17	0.25	0.67	0.25	0.08	0.08	0.08	0.25
Both water sectors	0.33	0.33				0.33				0.33	
Resources											
Water supply	0.25	0.67	0.75	0.75	0.08	0.25	0.17	0.17	0.17		0.08
Wastewater	0.42	0.25	0.67	0.75	0.25	0.17		0.08	0.17		0.17
Both water sectors		0.33	0.67	1.00				0.33	0.67		
Decisional level											
Ideal planning	Econ.	Plann.	Techn.	Mag.	Legal	Polit.	Envir.	Soc.	Educ.	OK	
Local	0.36	0.57	0.43	0.50	0.21	0.43		0.07		0.07	
Cantonal	0.40	1.00	0.20	0.20	0.20			0.20			
National	0.25	0.63	0.50	0.50	0.13			0.13	0.13		0.13
Barriers											
Local	0.50	0.29	0.07	0.21		0.43	0.14	0.07		0.21	
Cantonal	0.80	0.60		0.40	0.40	0.40	0.20				0.40
National	0.13	0.25	0.13		0.13	0.25			0.13		0.38
Resources											
Local	0.29	0.50	0.93	1.14	0.07	0.29	0.14	0.07	0.21		
Cantonal	0.60	0.60	0.80	0.60	0.40	0.20			0.20		
National	0.13	0.25	0.25	0.25	0.13			0.38	0.25		0.38

6.2.2. Decision level

Stakeholders from all three decision levels, the local (0.57), cantonal (1) and national (0.63) actors, mentioned planning aspects most often as important additional requirements to ideal planning (Tab. SD-F). These include catchment planning, horizontal and vertical collaboration. Other requirements mentioned often by the local actors were related to management & operation (0.50), which also applied to the national actors (0.50). The latter also mentioned technical aspects (0.50; local: 0.43), whereas the cantonal actors viewed economic aspects as second most important (0.40). Interestingly, the local actors mentioned political requirements often (0.43), which were not at all mentioned by the other two groups. The most often mentioned barriers for the local (0.50) and cantonal (0.80) actors concerned economic issues, which were seemingly of little importance to national actors (0.13). Other important barriers were political (local: 0.43; cantonal: 0.40; national: 0.25), or related to planning (local: 0.29; cantonal: 0.60; national: 0.25). However, it is noteworthy that a considerable number of cantonal (0.40) and national (0.38) actors could not give any statement concerning barriers; and for resources the same applied to the national actors (0.38).

For the local (1.14) and cantonal (0.60) actors management & operation was mentioned most often as important resource (national: 0.25), followed by technical aspects (local: 0.93; cantonal: 0.80; national: 0.25). Planning aspects were also viewed as resource (local: 0.50; cantonal: 0.60; national: 0.25), and for the cantonal actors economic aspects (0.60). Over one third of the national actors mentioned societal resources (0.38), which received little attention from the other two decision levels. On all three levels, about one fifth of the interview partners viewed education & research as a resource. Additionally, the cantonal actors mentioned legal topics often, both as barriers or resources (both 0.40).

6.2.3. Sector

For administration & politics, and science, planning aspects were mentioned most often as additional requirement to ideal planning (both 1.0), followed by technical aspects (administration & politics: 0.44; science: 1.0; Tab. SD-F). The same applied to practice stakeholders, but most often mentioned were aspects related to management & operation (0.56).

For practice, political barriers seemed most important (0.44), while for administration & politics economic barriers were mentioned most often (0.67). Barriers concerning planning were mentioned fairly often by both sectors (practice: 0.31; administration & politics: 0.44). The two interview partners from science mentioned economic, technical, legal, political and education & research aspects equally often (0.5) as barriers that hinder good planning.

The pattern concerning resources was similar as above, and most importantly seemed to concern management & operation and technical aspects. Both interview partners from science mentioned societal resources.

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Table SD-F. Continued.

	Economic	Planning	Technical	Managem. & Oper	Legal	Political	Environm ental	Societal	Educ. & Research	All OK	No comment
Sector											
Ideal planning	Econ.	Plann.	Techn.	Mag.	Legal	Polit.	Envir.	Soc.	Educ.	OK	
Practice	0.31	0.44	0.31	0.56	0.13	0.38		0.13	0.06	0.06	0.06
Administration & politics	0.33	1.00	0.44	0.33	0.22			0.11			
Public	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH
Science	0.50	1.00	1.00		0.50						
Barriers											
Practice	0.31	0.31	0.06	0.13		0.44	0.06	0.06		0.13	0.13
Administration & politics	0.67	0.44		0.33	0.22	0.22	0.22			0.11	0.33
Public	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH
Science	0.50		0.50		0.50	0.50			0.50		
Resources											
Practice	0.19	0.50	0.75	0.94	0.06	0.25	0.13	0.13	0.31		0.13
Administration & politics	0.44	0.33	0.67	0.56	0.33	0.11			0.11		0.11
Public	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH
Science	0.50	0.50	0.50	0.50				1.00			
Sector details											
Ideal planning	Econ.	Plann.	Techn.	Mag.	Legal	Polit.	Envir.	Soc.	Educ.	OK	
Engineers & industry		0.50	0.75	0.75		0.50					
Operators	0.50	0.50	0.25	0.50	0.25	0.50		0.13		0.13	
Administration water supply	0.50	1.50	0.50		0.50						
Administration wastewater	0.50	1.00	0.50	0.75				0.25			
Administration others		0.67	0.33		0.33						
Politics	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH
Public	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH
Water associations	0.25	0.25		0.50				0.25	0.25		0.25
Science	0.50	1.00	1.00		0.50						
Barriers											
Engineers & industry	0.25	0.50				1.00	0.25	0.25			
Operators	0.50	0.25	0.13	0.25		0.25				0.25	
Administration water supply	0.50	1.50		0.50							
Administration wastewater	1.25	0.25		0.50	0.50	0.50	0.50				0.25
Administration others										0.33	0.67
Politics	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH
Public	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH
Water associations		0.25				0.25					0.50
Science	0.50		0.50		0.50	0.50			0.50		
Resources											
Engineers & industry		1.00	1.00	1.00		0.25			0.75		
Operators	0.38	0.38	1.00	1.25		0.38	0.25	0.13			
Administration water supply	0.50	0.50	1.00	0.50	0.50				0.50		
Administration wastewater	0.50	0.25	0.25	0.75	0.50	0.25					0.25
Administration others	0.33	0.33	1.00	0.33							
Politics	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH
Public	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH
Water associations		0.25		0.25	0.25			0.25	0.50		0.50
Science	0.50	0.50	0.50	0.50				1.00			

6.2.4. Sector details

The patterns concerning additional requirements to ideal planning were similar for all sectors and mainly concerned economic, planning, technical and management & operational aspects (Tab. SD-F). However, it is interesting that engineers & industry, as well as operators mentioned political requirements (both 0.50), which were not at all mentioned by administration, the water associations and science. Consequently, the engineers viewed political topics as important barriers (1.0), which was mentioned less often by the other sectors (operators: 0.25; administration wastewater: 0.50; water associations: 0.25; science: 0.50), and not at all by the stakeholders from water supply administration and “other” administration. The administration wastewater (1.25) seemed to be strongly confronted with economic barriers and to some extent also the operators (mentioned most often as barrier in this group) and the administration water supply (both 0.50).

In all groups except water associations, there was a strong focus on technical resources, as well as on planning and management & operation aspects. The water associations most often mentioned education & research as resource (0.5), together with engineers & industry (0.75) and the administration water supply (0.5), while this was not at all mentioned by all the other sectors. Both science actors mentioned societal resources (1.0), which seemed less important – if at all – for all other sectors.

6.2.5. Private/ communal

The private actors mentioned additional requirements concerning technical and management & operational aspects most often (both 0.75), but also mentioned political and planning requirements (both 0.5; Tab. SD-F). The pattern was similar for communal actors, with planning requirements being mentioned most often (0.70). Communal actors also mentioned economic (0.39), legal (0.22) and societal (0.13) requirements, which were not at all mentioned by the private actors.

The private actors viewed political barriers as most important (1.0; communal: 0.26), while for the communal actors economic barriers were mentioned most often (0.48; private: 0.25).

Resources for both types of actors were in the fields of planning, technical aspects and management & operation. Education & research was also often mentioned as resource by the private actors (0.75), but far less often by communal actors (0.13).

Lienert, Schnetzer, Ingold (2013) Stakeholder analysis combined with social network analysis provides fine-grained insights into water infrastructure planning processes. Journal of Environmental Management 125: 134-148.

Table SD-F. Continued.

	Economic	Planning	Technical	Managem. & Oper	Legal	Political	Environm ental	Societal	Educ. & Research	All OK	No comment
Private / communal											
Ideal planning	Econ.	Plann.	Techn.	Mag.	Legal	Polit.	Envir.	Soc.	Educ.	OK	
Private		0.50	0.75	0.75		0.50					
Communal	0.39	0.70	0.35	0.39	0.22	0.17		0.13	0.04	0.04	0.04
Barriers											
Private	0.25	0.50				1.00	0.25	0.25			
Communal	0.48	0.30	0.09	0.22	0.13	0.26	0.09		0.04	0.13	0.22
Resources											
Private		1.00	1.00	1.00		0.25			0.75		
Communal	0.35	0.35	0.65	0.74	0.17	0.17	0.09	0.17	0.13		0.13
Main interest											
Ideal planning											
Economic		0.50	0.75	0.75		0.50					
Technical	0.50	0.60	0.30	0.40	0.30	0.40		0.10		0.10	
Civil societal	0.29	0.71	0.14	0.29	0.14			0.29	0.14		0.14
Environmental	0.33	0.83	0.67	0.50	0.17						
Barriers											
Economic	0.25	0.50				1.00	0.25	0.25			
Technical	0.60	0.20	0.10	0.30		0.20	0.10			0.30	
Civil societal	0.29	0.57		0.14	0.14	0.29					0.43
Environmental	0.50	0.17	0.17	0.17	0.33	0.33	0.17		0.17		0.33
Resources											
Economic		1.00	1.00	1.00		0.25			0.75		
Technical	0.40	0.30	0.90	1.20	0.10	0.30	0.20	0.10			
Civil societal	0.29	0.57	0.29	0.43	0.29			0.14	0.43		0.29
Environmental	0.33	0.17	0.67	0.33	0.17	0.17		0.33			0.17
Water interest											
Ideal planning	Econ.	Plann.	Techn.	Mag.	Legal	Polit.	Envir.	Soc.	Educ.	OK	
Water use	0.35	0.60	0.35	0.40	0.20	0.30		0.15		0.05	0.05
Water protection	0.29	0.86	0.57	0.57	0.14				0.14		
Other	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH
Barriers											
Water use	0.45	0.35	0.05	0.20	0.05	0.40	0.10	0.05		0.15	0.15
Water protection	0.43	0.29	0.14	0.14	0.29	0.29	0.14		0.14		0.29
Other	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH
Resources											
Water use	0.30	0.50	0.75	0.90	0.15	0.20	0.10	0.05	0.20		0.10
Water protection	0.29	0.29	0.57	0.43	0.14	0.14		0.43	0.29		0.14
Other	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH	no SH

6.2.6. Main interest

Those actors that we had assigned to following mainly economic interests, mentioned as additional requirements to today's planning mainly technical and management & operational aspects (both 0.75; Tab. SD-F). For the actors that were assigned to have technical, civic societal or environmental interests, requirements related to planning were mentioned most often (0.60, 0.71, 0.83, respectively). Again we point out that planning aspects include regional catchment planning, horizontal and vertical collaboration. The actors with economic interests mentioned political barriers most often (1.0), which seemed to be of far less importance to the other three groups. The actors with technical interests, but also those with environmental interests, mentioned economic barriers most often (0.60, 0.50, respectively), and those with civic societal interests planning barriers (0.57). Interestingly, the actors that we assigned to have mainly environmental interests did not mention environmental barriers (0.17) markedly more often than the economic (0.25) or technical (0.10) group. Legal barriers were mentioned by the societal (0.14) and environmental (0.33) "interest groups", but not by the two others and societal barriers only by the economic group (0.25). One third of the actors that were assigned to have technical interests did not perceive any barriers at all and about the same number of actors with societal or environmental interests could not give a statement concerning this topic.

The resources were seen to lie especially in the fields of planning, technical aspects and management & operation in all four groups (with different priorities, see Tab. SD-F). Education & research seemed important resources for actors with economic (0.75) and societal interests (0.43), but not for the other groups. Environmental resources, i.e. the water from Lake Zürich, were mentioned by the group with technical interests (0.20), but not the others.

6.2.7. Water interest

Finally, planning aspects seemed to be equally important requirements for an ideal planning process for both types of actors that are mainly interest in water use (0.60) and water protection (0.86; Tab. SD-F). The most often mentioned barriers were also the same, namely economic ones (water use: 0.45; water protection: 0.43), as well as planning aspects (0.35, 0.29, respectively). However, especially the actors interested in water use also often mentioned political barriers (0.40; water protection: 0.29). In contrast, the actors interested in water protection often mentioned legal barriers (0.29), which seemed of marginal importance to the water use actors (0.05).

As the analyses above showed for many groups, the main resources were mentioned to be in the fields of management & operation (water use: 0.90; water protection: 0.43), followed by technical resources (water use: 0.75; water protection: 0.57). The water protection group additionally mentioned societal resources often (0.43), which were not at all perceived as important by the water use actors (0.05). Both groups mentioned economic topics fairly often (0.30, 0.29, respectively), planning aspects (0.50, 0.29, respectively), but also education & research (0.20, 0.29, respectively).

6.3. Stakeholders that can overcome barriers or provide resources, how to overcome barriers

Table SD-G. Overview of stakeholders that can overcome barriers or provide resources. Number of times an actor was mentioned to have the possibility to overcome a barrier concerning a specific topic or to provide resources. The nine main topics are detailed in Tab. SD-E. Ba: Barrier, Re: Resource, WS: water supply; WW: wastewater; WWTP: wastewater treatment plant.

	Economic		Planning				Technical				Management & operation			Legal			Political		Environ-ment.	Societal		Education & research		Sum		Summary over decisional level			
Topics	Econ mone y	Econ perso nnel	Plann effic	Plann catch m	Plann horiz	Plann vert	Techn data	Techn tools	Techn infrast r	Techn equip m	Mana g harm oniz	Mana g com relat	Mana g profes s	Legal compl	Legal regul	Legal comp et	Polit syst	Polit supp	Envir	Soc partic	Soc aware	Educ pract	Educ sci						
Topic number	11	12	21	22	23	24	31	32	33	34	41	42	43	51	52	53	61	62	7	81	82	91	92						
Stakeholder	Ba	Re	Ba	Re	Ba	Re	Ba	Re	Ba	Re	Ba	Re	Ba	Re	Ba	Re	Ba	Re	Ba	Re	Ba	Re	Ba	Re	Ba	Re			
Engineers		2				1	3		6		1		3	1	12		1					2		5	27				
Other WS and WW industry						1																	0	1					
Other utilities (electricity, telecommunication, construction companies)					1														1				2	0					
Operators and operating staff (WS, WWTP)					1							1	2				1				1		0	6					
Regional water supplier (GWVZO)					1					2			1						1				0	5					
Water suppliers, WWTP and joint regional associations (incl. GWVZO)		1			1			6	1	1	1		1	7		1	2						2	20					
Community, communal authorities etc. without politicians				1		1		7	1		1		3	7		2						1		0	24				
Community, communal authorities etc. with politicians	4	3			3		1					2			1	1			2	2				14	5				
Community, office for underground engineering						1						2												0	3				
Community, only politicians	1			1													2							4	0				
Population	2	4											1								2	1	2	3	9	Local	30	100	
Cant. authorities, only AWEL (cant. agency for waste, water, energy and air)	1			2	1	1	3	2					3			1	1	1		1				7	10				
Cantonal authorities, only AWEL plus politicians	3	3																						3	3				
Cantonal agency for drinking water quality (cantonal laboratory)					1																			0	1				
Cantonal insurance on buildings GVZ (fire)		1					1	1																0	3				
Cantonal office for landscape and nature, ALN							1																	0	1				
All cantonal offices and politicians					1	1										1							1	2	Cantonal	11	20		
Swiss associations of WS and WW professionals SVGW and VSA)	1				1	1							1	1		1			1			1	3		5	6			
National authorities: federal office for the environment FOEN, WS and WW				1									2											1	2				
National authorities: FOEN, WS and WW, and politicians	3	1						1																4	1				
National politicians																								0	0				
All politicians (local, cantonal, national)															1		3	1			1			5	1				
All nat. authorities: environ., health, agric. (FOEN, FOPH, FOAG) and politicians					1																			0	1				
Non-Governmental Organizations NGOs																					1			0	1				
Swiss federal institute of aquatic science and technology Eawag, WS and WW	1																		1			1	1	1	3	2	National	18	14
Swiss national science foundation (SNSF)								1																	1	0			
Association of the cantons, East Switzerland (Verein d. Ostschw. Kantone, VOK)					1																			0	1				
Water treatment works of Zürich Oberland (Seewasserwerke ZH Oberland)					1																			0	1				
Media																								1	0	New SH	2	2	
Sum per sub-topic	16	12	3	0	1	1	6	0	5	16	0	4	1	23	2	2	0	3	0	3	0	0	0	0	61	136			
Sum per main topic			31							33			34				50			11		12	7	10	9	197			

Lienert, Schnetzer, Ingold (2013) Stakeholder analysis combined with social network analysis provides fine-grained insights into water infrastructure planning processes. Journal of Environmental Management 125: 134-148.

Table SD-H. Suggestions how to overcome barriers, and which stakeholders can (or should) do that. We show suggestions in words how to overcome barriers in each of the nine main topics, the times this was mentioned (x) and the stakeholder(s) that can (or should) overcome the respective barrier (grouped according to sub-topics; see Tab. SD-E). We only show those sub-topics where a suggestion of how to overcome a barrier was made (e.g. the sub-topic 31 "Technical, data" was deleted"). WWTP: wastewater treatment plant; comm: communal; cant: cantonal; nat: national; assoc: association; AWEL: cantonal agency for waste, water, energy and air; FOEN: federal office for the environment; GWP: Generelle Wasserplanung (a certain type of water supply planning); GEP: Generelle Entwässerungsplanung (a certain type of urban drainage planning).

	1. Economic			2. Planning			3. Technical			4. Management & operation			5. Legal		
	How to overcome barrier	x	Stakeholder	How to overcome barrier	x	Stakeholder	How to overcome barrier	x	Stakeholder	How to overcome barrier	x	Stakeholder	How to overcome barrier	x	Stakeholder
11 Econ money	Subventions; raise water tariffs	3	Community; cant. & nat. authorities												
12 Econ personnel	Active search for personnel; employ non-Swiss engineers	3	Engineers; water suppliers; WWTP												
21 Plann effic															
22 Plann catchm				Professionalization; regional planning of functional spaces by nat. authorities	2	Community; FOEN									
23 Plann horiz				Better collaboration betw. community & canton/ betw. sectors; raise awareness about canton	3	Community; AWEL; other utilities									
32 Techn tools							Harmonized software with automatic registration of all data	1	Community						
43 Manag profess	Professional financial planning; transparent procurement by tender procedure	3	Community	Keep time schedules (GWP); increase pressure f. integration (awarding authorities)	2	Engineers; comm. politicians				More professional management; less bureaucracy; find good lawyer	3	Water suppliers; WWTP; community	Transparent procurement by tender procedure	1	Community
52 Legal regul				Additional (lega) regulations, coordination, and strategic planning	1	AWEL; cant. offices & politicians	Open market / internationalization	1	Nat. authorities				Public procurement law is set (or change law); quality standards requirements	2	All politicians; community; AWEL
53 Legal compet	More competencies for operator (change communal regulations)	1	Comm. politicians												
61 Polit syst															
62 Polit supp	Political support	1	Cant. & nat. authorities												
7 Environ															
82 Soc aware	Make water bill/ infrastructure costs plausible to population	2	Population; nat. authorities; Eawag												
91 Educ pract	Awareness raising of importance of water and that it should cost	1	AWEL; assoc. of water professionals	Integrated terms of reference; education	1	Assoc. water professionals				Education	2	Engineers; assoc. water professionals	Education & innovation; drive for quality; employ foreign engineers	1	Engineers
92 Educ sci							Finance industrial and research projects	1	Swiss National Science Foundat.						
10 OK															
NA No comm															
ME New: Media															

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Table SD-H. Continued.

		6. Political		7. Environmental		8. Societal		9. Education & research		OK	No.c	Sum
		How to overcome barrier	x Stakeholder	How to overcome barrier	x Stakeholder	How to overcome barrier	x Stakeholder	How to overcome barrier	x Stakeholder			
11	Econ money											3
12	Econ personnel											3
21	Plann effic	Choose the most cost-efficient and technically best solution	1 All politicians									1
22	Plann catchm											2
23	Plann horiz											3
32	Techn tools											1
43	Manag profess											9
52	Legal regul			Controlling of existing planning tools ("GEP-checks")	1 AWEL							5
53	Legal compet	More competencies of operator	1 Comm. politicians									2
61	Polit syst	Accept lack of political continuity; change/ decouple from political system; more long-term thinking	5 Comm. politicians; AWEL; all politicians									5
62	Polit supp											1
7	Environ			Include sustainability considerations	2 Other utilities; community							2
82	Soc aware					Awareness about infrastructure	1 Population					3
91	Educ pract			Put new organizational structures into practice	1 Assoc. water professionals			Interdisciplinary environmental engineering studies	1 Assoc. water professionals			7
92	Educ sci			Make recommendations for new organizational structures	1 Eawag			Interdisciplinary environmental engineering studies	1 Eawag			3
10	OK									3		3
NA	No comm	No suggestion overcome barrier	3 NA								5	
ME	New: Media					Media: raise awareness	1 Media					1

7. Future uncertainties

At the end of the interviews, we asked the stakeholders to name uncertain factors that could influence the region until about 2050 and which could affect water supply and wastewater infrastructures. We classified these into the following 11 topics:

1. **Economic:** economic development; financing of infrastructure; increase of insured events that affect water infrastructures; financial development of associates (i.e. joint regional cooperatives); availability of financial instruments; public expenditures.
2. **Water consumption:** water consumption and prices; development of water consumption; development of water consumption depending on the water price.
3. **Spatial planning:** availability of (building) zones; settlement development; urban sprawl; agglomeration; development of the agricultural sector; increase in weight of trucks; increase in volume of private and commercial traffic.
4. **Demographic:** demographic development of population; population growth.
5. **Technical:** technical development of wastewater infrastructure solutions; technical development of water treatment; technical development of water protection; infiltration of stormwater; claims of population regarding accuracy of measurement; complexity and durability of control systems; development of gauges and accuracy of measurement.
6. **Organizational & political:** change in organizational structures: end of cooperative due to lack of personnel; privatization; change in organizational structures: compound for water purification; change in organizational structures: more lake water; political representation: pro or contra infrastructure rehabilitation.
7. **Legal:** development of legislation, norms, and guidelines.
8. **Pollutants:** development of water quality; new micropollutants.
9. **Energy & nutrient recycling:** energy availability; energy generation from wastewater treatment; recycling of sludge and phosphorus; resource management: sludge and phosphorus.
10. **Climate change:** climate change; availability of water resources; droughts and extreme rainfall; glacier decline.
11. **Terrorism:** incidents of terrorism and sabotage.

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Table SD-I. Uncertain future factors. We show the classifications of the interview partners as used in other tables (Tab. SD-B), the perceived risk and the times a topic was mentioned for each actor (sum given on last row). Risk perception: positive scale from 0 (neutral) to +10 (very confident about future and that topic can be dealt with in a positive way); negative on scale from -10 (extremely worried about negative consequences) to 0 (neutral). WS: water supply; WW: wastewater; WWTP: wastewater treatment plant; cant: cantonal.

Decis. level	Sector	Water sector	Sector detail	Inter-est	Water inter-est	Priv./communal	Community	Stakeholder	Inter-view no.	SH No.	Stakeholder abbreviation	Risk perception: positive	Risk perception: neutral	Risk perception: negative	Economic	Water consumption	Spatial planning	Demographic	Technical	Organizat. & political	Legal	Pollutants	Energy & nutr. Recycl.	Climate change	Terrorism
3	4	2	9	4	2	2	2	6 WW Swiss federal institute of aquatic science and technology Eawag (wastewater)	1	41	WW Eawag	2 (global)		-2 (CH)	1			1						1	
1	1	1	2	2	1	2	2, 4	WS regional water supplier (regional cooperative directorate, associates)	2	11	WS water supplier cooperative	7.5					1				1				
1	1	1	2	2	1	2	2, 4	WS regional water supplier (regional cooperative directorate, associates)	3	11	WS water supplier cooperative	5					1	1		1		1		1	
1	1	1	2	2	1	2	2, 4	WS regional water supplier (regional cooperative directorate, associates)	4	11	WS water supplier cooperative		0				1	1				1		1	
1	2	2	4	2	1	2	1, 2	WW municipal administration for wastewater	5	15	WW munic. admin.		0		1		1							1	
2	2	2	4	4	2	2	5	WW cant. agency for waste, water, energy and air (AWEL, wastewater)	6	24	WW cant. agency AWEL	5			1		1	1						1	
1	1	2	2	2	1	2	4	WW joint regional WWTP association, WW municipal managing board for underground engineering, wastewater	7	12, 16	WW joint WWTP assoc.	6			1			1							
2	2	2	4	3	1	2	4	WW cant. agency for waste, water, energy and air (AWEL, wastewater)	8	24	WW cant. agency AWEL		0 (drinking water)	-3 (wastewater)	1					1		1		1	
1	1	2	2	2	1	2	2	WW joint regional WWTP association	9	12, 16	WW joint WWTP assoc.	10					1		1				1		
1	1	1	2	2	1	2	5	WS regional water supplier (GWVZO management, operation, associates)	10	10	WS water supplier GWVZO	8			1	1	1			1				1	
1	1	1	1	1	1	1	2, 4	WS local engineer	11	1	WS local engineer	5					1		1					1	
1	1	1	1	1	1	1	2, 4	WS local engineer	12	1	WS local engineer	8 (technical)		-2.5 (water resources)	1	1		1				1		1	1
1	1	3	2	2	1	2	1	WS operating staff & emergency response team WW operating staff (urban drainage, WWTP)	13	8, 9	WS operating staff, WW operating staff	5			1	1	1	1	1	1			1	1	
1	2	3	5	2	1	2	1	WS municipal administration for water supply, WW municipal administration for wastewater	14	13, 15	WW munic. admin., WS munic. admin.	5 (CH)		-3 (global)			1	1				1		1	
3	1	3	8	3	2	2	6	Swiss network of actors in the water sector "Water-Agenda 21"	15	34	Water-Agenda 21	2.5 (technical)		-5 (population growth)			1		1	1					
2	2	2	5	4	2	2	5	WW cant. office for landscape & nature ALN (dept. hunting & fisheries)	16	28	WW cant. office fisheries ALN	7.5			1			1				1	1	1	
2	2	1	3	3	1	2	5	WS cant. agency for waste, water, energy and air (AWEL, water supply)	17	23	WS cant. agency AWEL	2.5			1	1	1	1		1		1		1	
1	1	1	2	2	1	2	3	WS operating staff & emergency response team	18	8	WS operating staff	7					1	1	1		1				
3	2	2	4	4	2	2	6	WW Federal office for the environment FOEN, division water, quality of surface waters section	19	36	WW nat. surface water FOEN	2			1		1							1	
1	1	2	1	1	1	1	4	WW local engineer (urban drainage, WWTP)	20	2	WW local engineer	5					1				1			1	
3	4	1	9	4	2	2	6	WS Swiss federal institute of aquatic science and technology Eawag (water supply)	21	40	WS Eawag	7.5			1		1		1		1				
1	1	2	1	1	1	1	2, 3	WW sewer maintenance companies	22	6	WW sewer companies		0		1									1	
3	1	1	8	3	1	2	6	WS Swiss association of gas and water professionals SVGW	23	32	WS nat. assoc. SVGW	5			1			1	1					1	
3	1	2	8	3	1	2	6	WW Swiss association of wastewater & water protection professionals VSA	24	33	WW nat. assoc. VSA	5				1			1				1	1	
3	2	1	3	4	2	2	6	WS Federal office for the environment FOEN, division water, groundwater protection section	25	35	WS nat. groundwater FOEN	10 (professional utilities)		-10 (small organizations)				1	1					1	
2	2	1	5	3	1	2	5	WS cant. insurance on buildings GVZ (fire)	26	27	WS cant. insurance fire GVZ	7.5					1		1					1	
3	1	2	8	3	1	2	6	Communal infrastructure association	27	33	WW nat. assoc. VSA	5			1	1	1	1	1				1		
Count												Positive: 23	Neutral: 4	Negative: 6	15	10	16	16	8	6	4	7	5	20	

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