NICHES DELIVERABLE D1.1 v2

CONCEPTUAL FOUNDATIONS: COMPARATIVE FRAMING OF NATURE-BASED SOLUTIONS FOR URBAN WATER MANAGEMENT IN EUROPE AND BEYOND

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1.   EXECUTIVE SUMMARY

1. Guiding recommendations are provided on approaches to understand and frame interdisciplinary and integrative research and innovation in nature-based solutions (NBS) for urban water management and particularly the issue of assessment of their impacts. The research focuses particularly on NBS relating to combined sewers networks and combined overflows (CSOs).

2. The research was undertaken through the Biodiversa- Water JPI NICHES project. The report summarises the outcomes of conversations between project partners and stakeholders around literature sets, structuring of interviews and surveys and frameworks for understanding interrelated issues in urban drainage.

3. Mapping of key issues, concepts, regulatory frameworks and impact assessment regimes was undertaken in conjunction with partners in the cities of Rotterdam (Netherlands), Berlin (Germany), Barcelona (Spain), Boston (USA) and Sheffield (UK). These partners came from different starting points in terms of disciplines, sectors, experiences and skill sets. The work commenced with establishing partners' interests, epistemologies and knowledge bases, as well as sketching out frameworks for integrating different contributions. The research then progressed to exploring characteristics of urban water management systems and contexts in each city, by establishing key questions and background information needs.

4. A routine was developed for undertaking both rapid and systematic literature reviews focusing on NBS pertaining to CSOs and urban water management in cities seeking to enable researchers to draw on publications from a broad set of fields whilst also focusing on key impacts and qualities of NBS versus conventional urban drainage systems.

5. The results provide insights that have shaped the development of the conceptual framework and impact assessment framework applied in subsequent workpackages and tasks in the NICHES project.

2.   INTRODUCTION

Background, purpose and overview of the research

Pollution and flooding from CSOs have increased with the impacts of climate change and biodiversity loss, and interest is increasing in the development of improved measures of success for future responses. This accompanies growing awareness of impacts of CSOs and a growing recognition that existing metrics based on numbers of overflow events and volumes alone are no longer sufficient.

This research, undertaken within the NICHES project sought to provide new insights into the framing of CSO impacts, interventions, and indicators (or measures of success). This report is the first of two deliverables in NICHES WP1, which has the goal to examine perceptions, institutions and infrastructures in the five cities (Rotterdam, Berlin, Barcelona, Boston, Sheffield).

The approach therefore involved exploring the framings and different understandings of the systems in place. This stimulated initial thinking within the partnership as a basis for future development of conceptual and impact assessment frameworks. However, the group quickly came up against barriers to the development of mutual understanding associated not only with differences in disciplinary backgrounds but the implications of contextual factors in shaping perspectives of priorities for both research and implementation into NBS for CSO control (NBS-CSO).

Taking a flexible and adaptive approach, new lines of enquiry were developed to explore the methods, models and metrics employed in managing stormwater in each system/city. In particular the work addressed key urban water management characteristics, priorities, methods and changes in these. Finally, the research tackled the issue of how to explore the potential impact assessment frameworks and associated indicators bearing in mind the need for these to address both conventional (grey) systems and approaches utilising NBS.

CSOs and urban water management in context

Around the world, cities stormwater management systems are increasingly unfit to cope with climate change impacts and flashier flows linked with more frequently intense and extreme runoff. The result is that CSOs are a source of pollution when combined drainage systems are overwhelmed, with overflows of untreated sewage being discharged into receiving waters, as well as sewage backing up into homes and businesses when systems reach capacity. Weir outlets associated with CSOs were designed to reduce pressure in such systems but were often designed for much lower flooding return periods than are frequently experienced today. Although closely associated with diffuse urban pollution, CSOs are classed as point sources of pollution.

Techniques employing NBS such as sustainable urban drainage systems (SUDS, D'Arcy et al, 1998) rely on infiltration, retention, detention and progressive treatment of urban water in stormwater management trains, employing vegetated interventions such as swales and rain gardens. These techniques were drawn from systems developed in the USA known as urban water best

management practices, which were often implemented in separate drainage networks. The thinking around SUDS was developed with the intention to address water quality, water quantity, amenity and biodiversity benefits, drawing on 'nature's way' including the various processes outlined above (treatment through vegetation and substrates, infiltration, detention and retention). Whilst the knowledge employed was largely based on techniques associated with diffuse pollution control and separate drainage networks, calls have strengthened over the years implement SUDS in combined systems in order to control CSO impacts.

Pollution from CSOs is complex and a function of the drainage area concerned; this can include household sewage or industrial drainage contributions but invariably includes bacteria, pathogens, solids, chemicals and oils. These discharges also contain high levels of nutrients which have the effect of causing eutrophication as well as being linked with human health problems. The negative impacts on recreation, wellbeing, nature and aesthetics are becoming increasingly well known, particularly but not exclusively in urban environments. The scale of the problem at the EU level is significant and growing (EEA, 2018; EC, 2019a&b; Quaranta et al., (2022).

It is against this backdrop that research into alternative approaches to urban drainage has evolved quickly (Fletcher et al., 2015), with numbers of associated publications growing rapidly (Ruangpan et al., 2020). Whilst this represents a vital knowledge base for researchers and practitioners, the burgeoning literature also presents significant challenges for those seeking to understand potential responses and impacts of alternative approaches to urban water management. The multiplicity of research methods and disciplinary understandings at play can be considered both a strength and a weakness. The wide scope of epistemologies and framings have important implications when it comes to considering new ways to measure success and to to understand the impacts, benefits and investment decisions around urban water management in the future.

Traditionally, many studies have not properly considered the wider co-benefits of SUDS or their integration within wider green infrastructure networks (Ashley et al., 2011). Attempts to improve upon the comprehensiveness of assessment include CIRIA's B£ST toolkit, and more widely for NBS, holistic frameworks for impact assessment (Raymond et al., 2017; Dumitru & Wendling, 2021a). The development of these impact assessment approaches offers an important backdrop against which to consider combined sewers and water quality (and vice versa), giving the overall context for this research conducted within the Biodiversa+ NICHES project.

3. METHODS

Overview of methods

Research in this task entailed two main steps. The first step started with initial exploratory conversations around key concepts and epistemologies employed by the partners in their work on urban water systems and NBS. Different framings of urban water management were then considered, drawing on these dialogues, leading to an agreed approach to interrogate literature sets. The second key step involved developing core themes and topics for interviews and surveys, to explore key characteristics of extant systems in each city.

Key concepts, framings and literature sets in NICHES

The starting point for this research was to review key publications noted in the NICHES proposal. This entailed critical evaluation of grey literature (e.g. EC publications) and academic journal articles used as foundational references in the bid (e.g. Ashley et al., 2015; Davis & Naumann, 2017; Teurlincx et al., 2019; McPhearson et al., 2021; Chang et al., 2021; Woroniecki et al., 2023).

Exploratory group work to further understand differing epistemologies and conceptual frameworks of interest in NICHES commenced at an online workshop 21-22 Apr 2022. This entailed an initial scoping process led by USFD in which partners considered how they understood notions of success in urban water management. In subsequent meetings (Sep 2022, Jan 2023), keywords and knowledge gaps (research and innovation needs) were explored, using simple Miro Board tables with post-it notes. Subsequently, mind-maps were created for each country/city, participants considered how partners could develop and share understandings of frameworks currently used in practice to set regulations for CSOs, key metrics, organisational stakeholders and drivers of change.

In this step, USFD, UAB, ECO and NIOO developed an outline framework to facilitate exchanges on epistemologies and comparative-constructive dialogues between partners. Initial attempts proved difficult because the approach needs to bridge theoretical perspectives, for significantly different place-based case study locations. The emerging frame drew on Langemayer & Connolly's (2020) work on justice in ecosystem services and Depietri & McPhearson's (2017) interpretation of SETS, with subsequent research also drawing on Woroniecki et al. (2023) conceptions of socio-ecological vulnerability. The approach was introduced and agreed at NICHES partner meetings in September 2022. To provide inspiration and situate the literature within the city contexts, a workshop was held online (M9) in which partners presented summaries of each case study and their associated research. Partners described their understandings of existing assets, constraints and opportunities of relevance to both the urban water management system and their associated research on NBS. The resulting presentations included material on stormwater management approaches, combined sewer network issues, hydrological and design factors and institutional economic frameworks.

Information from partners was collated on literature sets aligned with staff interests. This was structured according to infrastructures, institutions and perceptions, including temporal and spatial aspects (Fig.1). Partners were asked to identify relevant publications (own; other authors) within the resulting framework. The categories were kept deliberately broad to enable references to be drawn from social, ecological and technical bases, and their nexuses, relevant to SETS. Between September-October 2022, partners populated a shared document (Google Sheet templates) with references. From this, a master list of key words was developed and refined.

Perceptions green - spatial	Perceptions grey - spatial	Perceptions green - temporal	Perceptions grey - temporal
Institutions green - spatial	Institutions grey - spatial	Institutions green - temporal	Institutions grey - temporal
Infrastructure green - spatial	Infrastructure grey - spatial	Infrastructure green - temporal	Infrastructure grey - temporal

Figure 1. Categorising research fields in NICHES (after Depietri & McPhearson 2017; Langemayer & Connolly 2020)

Given the wide scope of literature sources, it was determined that a mixed-methods approach to literature review would be appropriate, with the intention to draw on freely available and restricted access (paywalled) tools alike, including Scopus and Google Scholar. However, this could potentially yield large sets of references, meaning that a date/year constraint would prove helpful. In this instance the recommendation would be to search publications from 2015 onwards – the point at which significant numbers of NBS publications become detectable.

Setting the overall themes and topics for interviews and surveys

Themes and topics for interviews were shaped by examining research activities by different partners. In summary this included: (1) USFD and ECO's work to develop a Berlin case study (reported separately); (2) work on the ecological resilience of Rotterdam waterscapes to extreme climate (NIOO); (3) Barcelona's research on vulnerabilities and SETS (UAB); (4) and NWU's introduction of nutrient flows and life cycle impacts of green and grey stormwater in Boston. This phase commenced with the production of a preparatory report (December 2022) setting out the proposed agenda and roles of partners.

A foundational workshop was held online with all partners in January 2023. This discussion involved partners jointly interrogating conceptual foundations and comparative framing approaches. Each partner organisation presented ideas for publications, highlighting relevant literatures, and conveying core interests, methods and priorities. These presentations covered specific SETS challenges in each city, partner research approaches, and preferred analytical frameworks. Talks were then discussed covering clarifications, followed by commentaries and critiques. Mapping of key issues, concepts, regulatory frameworks and impact assessment regimes was undertaken in conjunction with partners and stakeholders in the cities of Rotterdam, Berlin, Barcelona, Boston and Sheffield.

A second workshop was held in person (Barcelona, March 2023) with the aim to bring together knowledge and mutual understanding across the diverse case study contexts. Miro was used as a platform for mind-mapping. This research involved partners jointly exploring key characteristics of urban water management systems in place now. Material for each city was presented and systematised in a consistent manner, using common themes and hierarchies. This enabled us to explore which aspects of stormwater management are core to all cities or specific to certain cities.

A survey format for semi-structured interviews and desk-based work was developed by USFD with input from all partners, and was piloted in a separate city. The finalised survey was provided with guidance to all partners to support qualitative research with stakeholders.

Further work entailed interrogating the EC's NBS impact assessment handbook (Dumitru & Wendling (2021a&b). This involved examining criteria and indicators related to urban stormwater management, to provide insights into how transnational and local contexts might be bridged, to underpin WP1s comparative-constructive approach. The Berlin case study used was to highlight the impacts of CSOs and relevant NBS, different perceptions and change processes of urban water systems, and the formative events and changes in policies, thus also supporting future work steps.

4. RESULTS & DISCUSSION

Key concepts, framings and literature sets in NICHES

NBS research has tended to adopt and adapt key conceptual bases from sustainability and ecosystem services literature, but not necessarily in a comprehensive or consistent way. Reasons for this may be linked with dissatisfaction with progress towards key sustainable development goals or from a frustration with modelling and cataloguing processes associated with ecosystem services. Added to this is the complication that urban NBS and particularly interventions linked with water have been strongly allied with blue-green infrastructure models (focusing more on networks, links and nodes within planning frameworks). Further issues with NBS stem from critiques of solutionism (see Mercado et al., 2023) and overly anthropocentric modes/mindsets.

SETS (Depietri & McPhearson, 2017) represents an interesting departure point for research in urban water NBS in that it downplays economic aspects, whereas much of the urban water research has been strongly influenced by monetary valuation and cost effectiveness. Bringing together a range of different principles and interests is possible by integrating SETS frames together with models from the ecosystem justice literature. Figure 2 considers urban water NBS from the viewpoint of perceptions, institutions and infrastructures (after Langemayer & Connolly, 2020) which are key building blocks as regards justice in ecosystem services, and unites these with aligned domains of socio-economical, technical and ecological provided by SETS (Depietri & McPhearson, 2017).

Key to the SETS approach is also to foreground the nexuses between those three categories, so these are also made explicit in Figure 2 (for ease of reference, the socioeconomic-technical nexus is contracted here to socio-technical). Finally, we can consider key interventions (shown as shaded boxes) in terms of green and nature-based elements, grey/conventional/traditional components, and hybrid modes that integrate both. Within Figure 2, knowledge relating to urban water management is shown within the triangle, echoing D'Arcy's (1998) SUDS conception, but addressing a wider range of drivers and imperatives than flooding, pollution, biodiversity and amenity. A key challenge in this discussion of framing is how it can be operationalised in research terms. This brings us on to the related topic of literature review and key words.
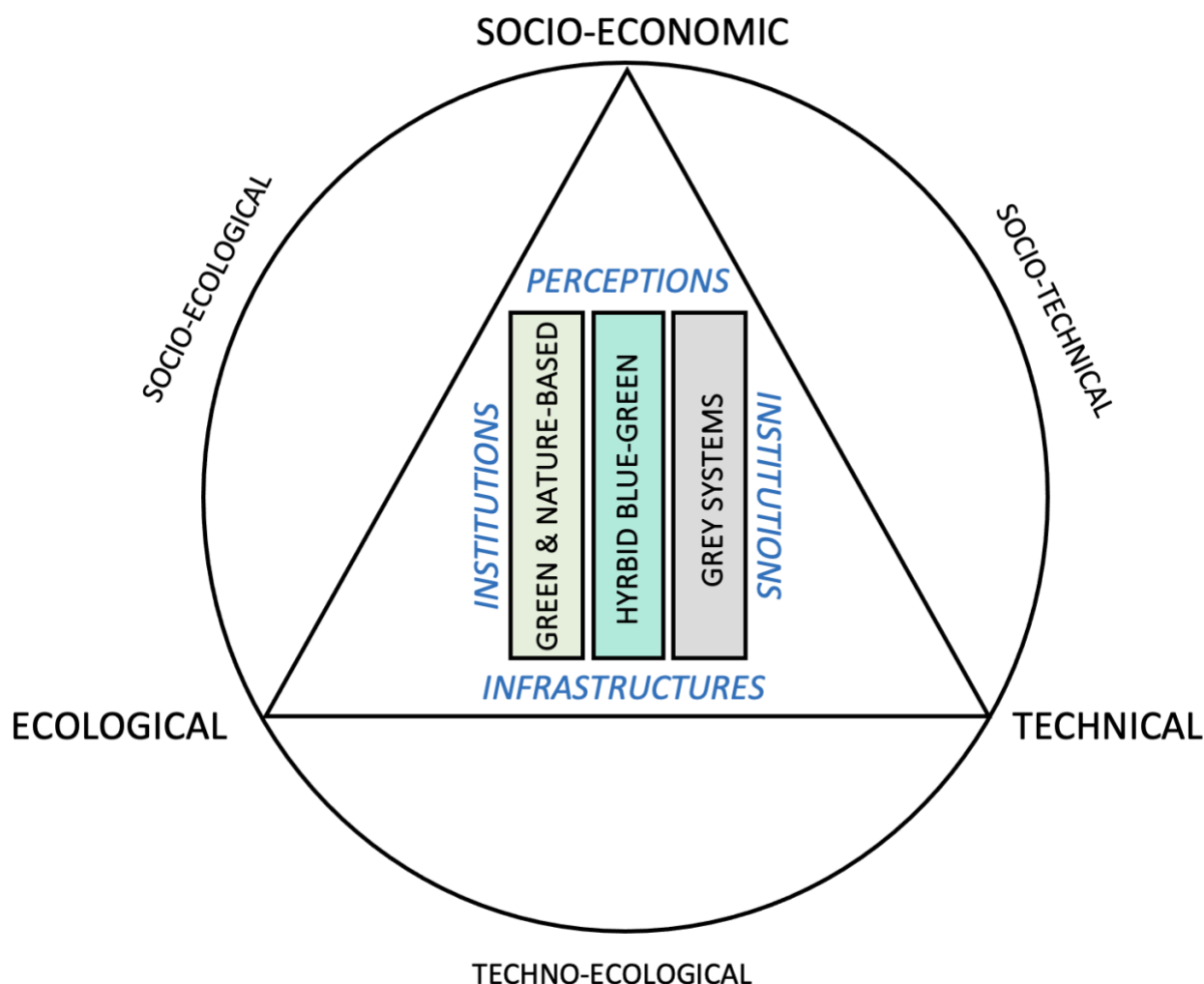
Figure 2. NICHES framing of NBS for urban water management (after D'Arcy, 1998, Depietri & McPhearson, 2017, Langemayer & Connolly, 2020)

Figure 2 provides a range of key terms that in principle could be applied within a systematic literature review. However, before launching into such a time-intensive process, it is important to consider where the focus of the NICHES project team sits. In the initial scoping work carried out to situate partners research interests (Fig.1), the majority of references were found to relate to green and nature-based approaches, and also tended to be focussed on the left-hand side of the triangle. Few references pertained to technical, or socio-technical elements, and fewer still related to econo-technical research. It is important to acknowledge this gap in capacities, particularly so because much of the urban water research literature traditionally sat in precisely this sub-domain.

The above descriptions highlight some of the key debates and conclusions reached through the top-down efforts to develop framing and boundary concepts in NICHES. In the coming phases it is intended to utilise this framework within targeted searches for NBS-CSO academic publications. However, this can also be complemented bottom up, by deriving key words for use in a systematic

literature review based on known publications of interest within the partnership. It is this approach that was taken in the next sub-task in WP1.

Using a subset of 43 filtered publications derived in step 1 of the research, keywords were extracted, generating a list of over 250 keywords. However many of these were closely aligned or duplicated. Even with the removal / rationalisation of these duplicates, far too many keywords remained, making a structured literature review deeply problematic. In response to this, keywords were systematised taking all permutations of the top 10 most frequently cited keywords (Figure 3). Nevertheless, open-ended searches still returned far too many references to be analysed within the scope of the project. Facing this result, the decision was taken to narrow the research down further, by focusing on one city, Berlin, which was also the primary case study in WP1.

	urban	water	green	infrastructure	nature	ecosystem	runoff	sewer	combined	overflow
urban	x									
water	urban water	x								
green	urban green	water green	x							
infrastructure	urban infrastructure	water infrastructure	green infrastructure	x						
nature	urban nature	water nature	green nature	infrastructure nature	x					
ecosystem	urban ecosystem	water ecosystem	green ecosystem	infrastructure ecosys	nature ecosystem	x				
runoff	urban runoff	water runoff	green runoff	infrastructure runoff	nature runoff	ecosystem runoff	x			
sewer	urban sewer	water sewer	green sewer	infrastructure sewer	nature sewer	ecosystem sewer	runoff sewer	x		
combined	urban combined	water combined	green combined	infrastructure combi	nature combined	ecosystem combined	runoff combined	sewer combined	x	
overflow	urban overflow	water overflow	green overflow	infrastructure overflc	nature overflow	ecosystem overflow	runoff overflow	sewer overflow	combined overflow	x

Figure 3. Top 10 keywords from 43 selected publications on urban water NBS (all permutations)

Thus, keywords shown in Figure 3 were combined with the additional search term 'Berlin', so as to provide manageable searches, using relevant phrases (e.g. Berlin urban water; Berlin water runoff, Berlin ecosystem sewer etc).

Peer reviewed literature where then reviewed based on a combination of the PRISMA systematic review reporting approach (Liberati et al., 2009; Moher et al., 2009) and restricted review methods (Plüddemann et al., 2018). Peer-reviewed publications were identified through Scopus and Google Scholar (dated 2015 - present). Search terms used in paired combinations included: urban; water; green; infrastructure; nature; ecosystem; runoff; sewer; combined; and overflow. This returned 313 references including duplicates, and 168 unique references once duplicates were removed. This is perhaps surprising, but it is evident that the relevant topics have been heavily researched. Berlin is clearly a frontrunner in this field of research.

In completing the review, abstracts were reviewed anonymously (removing author names and journal titles to reduce bias). Datasets were screened using the following exclusion criteria: (a) does not address urban water management or green infrastructure issues; (b) pertains to rural ecosystems; (c) does not relate to Berlin; (d) not peer-reviewed. Reasons for screening out abstracts were recorded, enabling cross-comparison between searches across the domains.

The resulting dataset included 82 references, following screening for the themes of stormwater, CSOs and urban watercourses in Berlin (Fig.1). Following a review of full texts, publications were grouped according to similarity of themes and challenges addressed. A paper based on the findings of this review, combined with qualitative research undertaken in Berlin, was submitted to a peer reviewed journal.

Overall, the methodological developments reported above are replicable and are promising in terms of wider application across all five NICHES cities. However, further constraints would be needed to account for the wider literature set, and it is recommended that this should be achieved by introducing the strict search term "nature-based solutions". This step will be completed in the subsequent WP1 deliverable, in Task 1.2.

Themes and topics for interviews and surveys

The results of the framing exercise and literature review were used alongside the above methods to formulate questions for future semi-structured interviews with city stakeholders, and background material surveys to be undertaken by NICHES partners. Themes and guiding subthemes for the survey and semi-structured interviews – which sought to establish common/shared issues and city-specific aspects – are shown in Annex 1 and summarised below:

Part 1: basic case study information (provided by partners): location, legislative and policy framework, drivers of change, stakeholders, models and metrics.

Part 2: semi-structured interview guidelines:
- Participant information ('about you'), background, interests in stormwater systems and understanding, means of obtaining information.
- Organisational information and/or political interests in stormwater: investment, management, charging, planning, modelling, decision-making, lobbying.
- Changes in stormwater management and combined sewer systems.
- Planning design, funding and management.
- Political framework, interests and representation of citizen interests.
- Perspectives on future measures of success.

Mapping of key characteristics of stormwater regulatory systems

Initial participative mind-mapping work conducted by the partnership provided insights into core interests in stormwater systems, and developed shared understanding of regulatory frameworks at play in each city. The framework for this, developed in the Jan 2023 meeting, is shown in Figure 4.
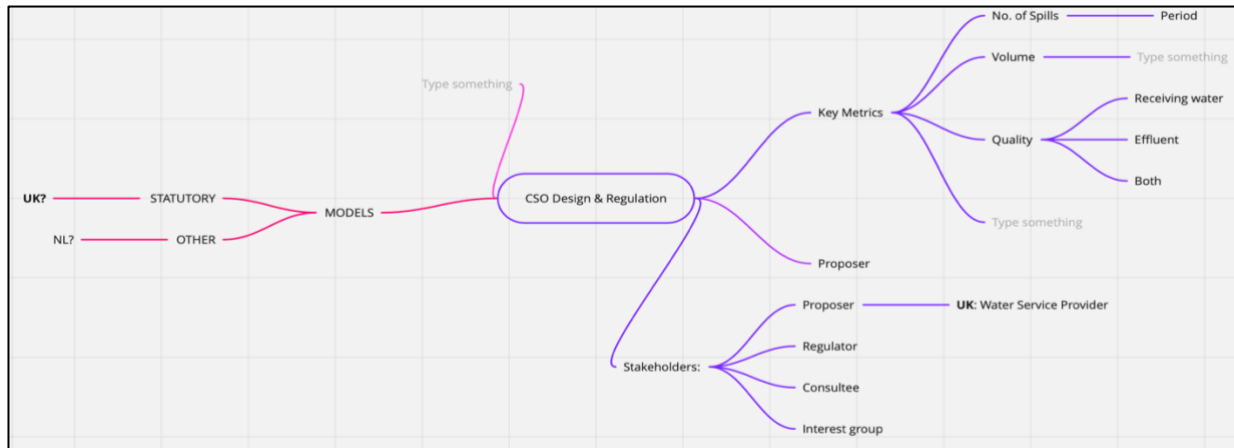
Figure 4. Initial mind-mapping – methodological development (Jan 2023)

Partners agreed to develop mind-maps for each case study city, with the important addition of details pertaining to drivers of change and governance innovation. Figure 5 summarises key components of the mind-map for one city (Sheffield), developed in the Mar 2023 workshop. The full set of mind-maps remains under development and results will be reported in deliverable D1.2.
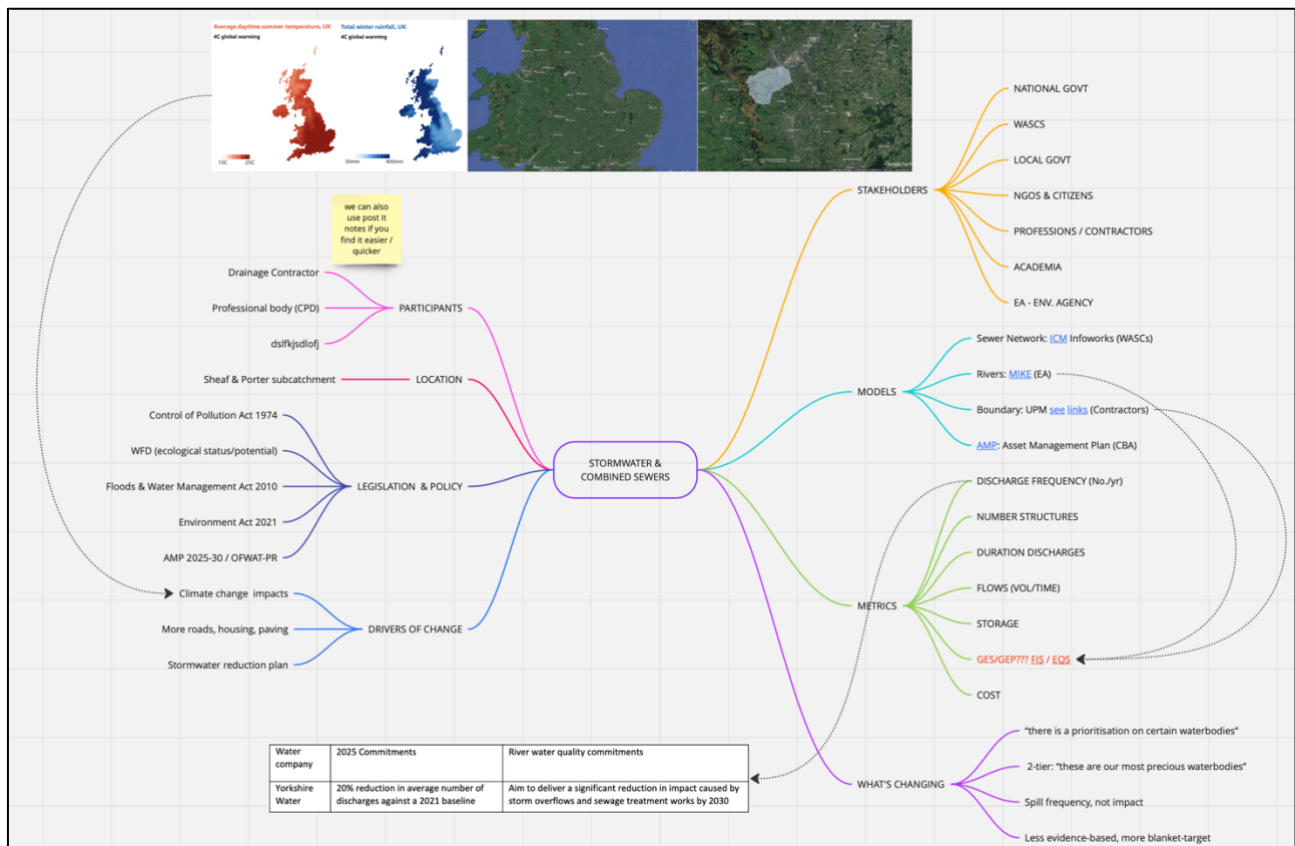

Figure 5. Example of NICHES mind-mapping of combined sewer system regulatory framework (Sheffield), Jan-2023

Comparing urban stormwater management themes with NBS impact assessments

Since NICHES is primarily concerned with urban NBS, attention was also given to methods to bridge between urban stormwater management practices and NBS impact assessment protocols. This is important in considering what interventions may be classed as NBS (what 'counts' as nature-based) and how they compare, integrate or conflict with other responses. Comparing key characteristics of CSO regulatory frameworks with NBS impact assessment frameworks offers significant promise in revealing important relationships including synergies and tensions at play. For instance, Sheffield has agreed goals for nature-based water management strategies under 8 key themes, several of which relate to high-quality rivers and ecosystems, but none pertain solely to pollution. At the wider catchment scale (the River Don catchment, roughly the same area as South Yorkshire), water management plans foreground pollution alongside other river issues such as connectivity. In principle both sets of plans can be compared against NBS assessment protocols, to illustrate key interests, dialogues and priorities at various scales.

This process was undertaken for the Berlin case study. Findings from the interviews and literature were analysed through comparison with the themes of the European Commission's NBS Impact Assessment Handbook, using its set of 'societal challenges areas' (Dumitru & Wendling, 2021a). This involved categorising issues addressed in the literature, and mapping them onto specific indicator types. Specific assessment methods (Dumitru & Wendling, 2021b - 'recommended and additional indicators') were analysed for relevant indicators. In this exploratory work, 6 themes key to stormwater management issues in Berlin were mapped on to societal challenges, indicators and evaluation methods presented in Dumitru & Wendling (2021a&b). Within these 6 key themes, 27 potential indicators were identified bottom-up from the data. These 27 Berlin-focussed topics related closely to 32 of the specific indicators in the NBS impact assessment framework, within 11 sections of that framework.

Interestingly, the potential Berlin indicators identified from the literature and interviews matched more closely with the detailed measures from Dumitru & Wendling (2021a&b) than did the broader thematic areas between the two datasets. Two of the key indicators pertaining to urban stormwater management issues in Berlin with economic relevance were not represented in the NBS impact assessment handbook.

Following this explorative work and the resulting insights it is recommended that mind-maps for each city should be compared against the NBS impact assessment handbook to ascertain what key links and gaps exist in each case (for the European cities only, since the handbook relates to NBS in Europe). Key topics for future discussion within the NICHES partnership meetings could be to compare these framings with the SETS approach, and to consider the issue of comparability as regards legal-institutional conditions. The applicability of the NBS impact assessment handbook and the Water Framework Directive in EU cities are important factors to consider in this respect.

5.   CONCLUSIONS & RECOMMENDATIONS

1. Semi-structured interviews and targeted literature reviews provide important methodological tools to explore extant conditions, changes influencing key decision-making processes, and institutions including socio-economic frameworks for investment and modelling approaches around urban stormwater management NBS.

2. Extensive literature reviews were possible for Berlin, but this might not be replicable in other less-well researched cities as regards urban stormwater management themes. Further work is required to determine and agree appropriate keywords for application in comparative-constructive research across all NICHES cities. This theme will be picked up in the subsequent WP1 deliverable. A conceptual starting point to discuss and agree keywords applicable for all (or multiple) cities is provided here in a tentative 'NICHES framing of NBS for urban water management' (Fig.2) based in part on the SETS framework and other relevant concepts.

3. Mapping of key themes for each city performed collaboratively (e.g. using Miro) shows promise in revealing key theme for further enquiry and its application in Berlin proved instructive in opening up key topics for qualitative research. This can be repeated for other cities.

4. A framework has been developed for semi-structured interviews and applied to provide insights into current and future challenges and responses as regards NBS for urban stormwater management. This methodology is replicable across all cities.

5. Comparison of the results of interviews, mind-maps and literature review findings with NBS impact assessment frameworks provides the opportunity to explore the relevance of - and implications for – those frameworks. However, an important point to consider and discuss is the applicable legal-institutional conditions and their comparability in EU or non-EU cities.

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ANNEX 1. NICHES survey and semi-structured interview guide: urban water NBS in case study cities

The purpose of this survey is to provide information about the NICHES cases, (a) including specific areas impacted by combined sewer overflows and stormwater management interventions, (b) the relationship of these assets with the sources of stormwater, and (c) the networks of beneficiaries that benefit from investments to resolve combined sewer overflow issues.

In particular, we are seeking to understand assets, constraints and opportunities. These extant conditions for the case cities may for instance include: existing infrastructure networks; knowledge of hydrological regimes and changes influencing combined sewers; and/or institutions such as economic frameworks for investment or modelling approaches that are frequently applied.

The information provided for each case study city will be used to establish what factors and considerations are core to all cities in their handling of stormwater and combined sewer issues c.f. concerns that are specific to certain cities, e.g. elements relating to cities' geographies, urban forms or hydrologies. The results will also be used to inform a report reflecting on formally adopted frameworks and protocols used to qualify and quantify stormwater management impacts and measures of success.

The survey is structed in two parts. <u>The first part</u> involves establishing the boundaries and conditions for the study, and can <u>be completed</u> by NICHES partners through desk studies or through a process of local discussions. This first part basically involves establishing some basic information about how combined sewers and stormwater management are managed and governed.

<u>The second part of the survey entails semi-structured interviews with local stakeholders</u>, coordinated via the local case study partners themselves. This process has been trialled in Berlin. Sets of suggested questions are provided, for generalised stakeholders. These questions can be adapted to suit the local case and interviewee (participant) as well as providing for an open format for the semi-structured interviews. The informed consent form is attached along with the participants information sheet.

(1). Basic information about the studied system (case study)

1a. **Location of the case**. Describe the physical boundary for the water management system when talking about CSO/rainfall management. If possible, provide a delineated map.

1b. **Legislative and policy framework**. What key laws and/or rules govern the ways in which stormwater management assets and combined sewers are planned, funded and managed? Please be specific, providing links to acts, laws, rules. At what scale do these laws and rules apply? (City? Catchment? State? National?)

1c. **Drivers of change**. What are the key trends and developments that are impacting these stormwater and combined sewer systems and their management?

1d. **Stakeholders**. Who are the key stakeholders that are involved in CSO and water management, having statutory responsibilities or main roles to play (e.g. as formal consultees) in the above processes and discussions? (e.g. which bodies and actors are responsible for the outlined policy framework in 1b)

1e. **Models**. What are the tools widely accepted for use in modelling stormwater systems and combined sewers to support decision-making around investment? Which organisation has the responsibility to apply the tools and who are the main users of the results in making investment decisions? What do they model?

1f. **Metrics**. What parameters are quantified and qualified using these model/s? In other words, what are the key measures of success that are generated through the application of the model/s?

Which other indicators of success are discussed or taken up in policies for stormwater management and CSOs (e.g. social impact such as awareness raising, recreational use, aesthetic appeal, participation, etc)?

(2). Menu of potential questions – picklist topics for semi-structured interviews with stakeholders

About you
2.1.   Job title, organisation and role of individual, educational background (all participants).
2.2.   Which aspects of the stormwater system are you interested in?
2.3.   Level of understanding of stormwater systems (Likert scale from low to high).
2.4.   How do you obtain knowledge with regards to these interests, e.g. from e.g. models, monitoring, stakeholder engagement, walk-over survey, wider literature, other experiences?

About your organisation
2.5.   Organisational or political interests in stormwater – e.g. business/revenue, capital investment, socio-economic impacts, environmental effects, citizen representation, greenspace planning and management.

2.6.   Is your organisation responsible for:

2.6.1.   Investing in combined sewer systems and/or stormwater management systems?
2.6.2.   Managing these systems and providing their services?
2.6.3.   Charging customers to use these systems?
2.6.4.   Planning these assets and understanding benefits of future investment in the systems?
2.6.5.   Modelling the systems and providing information about their current and future status?
2.6.6.   Making decisions around the overarching framework for the above processes?
2.6.7.   Lobbying for particular interests impacted by stormwater systems and combined sewers?
2.6.8.   Making other decisions or taking other actions that impact upon or are impacted by stormwater and combined sewer systems?
2.6.9.   Other (please specify)

What is changing?

2.7.   What is changing in your city with regards to the challenges being faced, and how is this affecting stormwater and combined sewer system planning, design, management and investment?

About the planning, design, funding and management of systems
If you answered Yes to any of questions 2.6.1-2.6.6, please also answer questions 2.8-2.12 inclusive. If not please go to question 2.13.

2.8.   What tools does your organisation use in modelling stormwater systems and combined sewers to support decision-making e.g. around investment?
2.9.   What are the key input and outcome impact indicators? If specific indicators are used, what are the attributes, units and system boundaries?
2.10. Is off-the-shelf modelling software used? What is the model/software name? Please can you provide a website link?
2.11. What are the boundaries for these models or systems and how to these boundaries relate to the specific systems or characteristics that are being modelled?

2.12. How have climate change implications been addressed in how these models are used, developed or applied?

Political framework, political interests and representation citizen interests

2.13. How has the political framework changed over time in response to CSO events and societal, economic and environmental impacts? If so, are changes due to citizen movements and demands?

2.14. In your city, what do you consider to be the key priorities of citizens for urban water systems, including drainage and rivers? Have these changed over time in response to CSO impacts?

2.15. What do you consider to be appropriate measures of success in the management of stormwater and combined sewer systems? Do you think different stakeholder groups would agree, or that they measure success differently?

Your thoughts on future measures of success in stormwater and combined sewer systems

2.16. How if at all do you think measures of success for stormwater management might change over time? (e.g. shift from grey to hybrid or green interventions, more participatory decision-making, etc)